

The anomalies of the ocular muscles / by George T. Stevens.

Contributors

Stevens, George T. 1832-1921.

Publication/Creation

[Place of publication not identified] : [publisher not identified], [1889?]

Persistent URL

<https://wellcomecollection.org/works/cx88er99>

License and attribution

This work has been identified as being free of known restrictions under copyright law, including all related and neighbouring rights and is being made available under the Creative Commons, Public Domain Mark.

You can copy, modify, distribute and perform the work, even for commercial purposes, without asking permission.



Wellcome Collection
183 Euston Road
London NW1 2BE UK
T +44 (0)20 7611 8722
E library@wellcomecollection.org
<https://wellcomecollection.org>

THE ANOMALIES OF THE OCULAR MUSCLES.

BY DR. GEORGE T. STEVENS, NEW YORK.

FIRST PAPER.

I.

AFFECTIONS of the ocular muscles may be divided into those which are physiological peculiarities and those which result from pathological conditions. It is proposed now to consider the first of these two groups.

In the normal adjustments of the eyes in the act of vision, two distinct classes of muscles perform each its separate office. The muscle of accommodation situated within the eyeball acting as focal adjuster for each eye, while the long muscles within the orbit direct the eyeballs in such a way as to bring the visual axes of the two eyes to bear upon the point for which the focal adjustment is made.

The two classes of muscles are in a sense independent of each other, yet in a very important sense in close and interdependent relation. In the discussion of the anomalies of the ocular muscles, then, the relation of these two classes is to be constantly regarded. The affections of the ciliary muscles, constituting the essential factor in the subject of the accommodation of the eye, become a subject of special study, and not to be considered in this connection further than in respect to the reciprocal influences of the two classes of muscles.

Such special conditions of the muscles of accommodation as may be necessary to refer to in order to obtain a proper understanding of their relations with the class of muscles more directly under consideration will be introduced as occasion demands.

The subject of anomalies of the directing muscular apparatus of the eyes divides itself again into two classes : first, those which permit of habitual binocular vision ; second, those in which a blending of the images of the two eyes is so difficult as to be, in most instances, impossible. In the first of these two classes of faults, binocular vision is maintained by the expenditure of a greater amount of force than is demanded in perfect equilibrium of the ocular muscles ; in the second, a psychical disturbance results which may have an important bearing upon the general physical condition of the individual subject of the anomaly. The two classes are in reality but different degrees of similar affections, and the classification depends upon the psychical presence or absence of the phenomenon of a fusion of images. Indeed, under certain circumstances, one of these conditions may pass into the other, and one who, in robust health, blends images habitually and with difficulty may, in a condition of impaired nervous energy, be quite unable to maintain a fusion of the images of the two eyes. Even the presence or absence of binocular vision, then, does not constitute an absolute and sharply defined line of classification. It also often happens that, with gross departures from the standard of equilibrium of the ocular muscles, habitual binocular vision is sometimes maintained, while in other instances comparatively moderate anomalies give rise to diplopia.

Such conditions must, however, be regarded as exceptional, and if the boundary, the sustained presence of single vision, like many of the boundaries of classification in science, is sometimes vague, it will on the whole be found practical and satisfactory.

Directing our observations first to the class of anomalies in which habitual binocular vision is maintained, we shall find a theme rich in interest and of pre-eminent importance in its practical bearing.

While it is true that some of the most illustrious names among those who have contributed to the notable progress of modern ophthalmology have been identified with the discussion of this subject, it is nevertheless also true that,

considered in respect to its importance, comparatively slight attention has been bestowed upon it in the literature devoted to ocular affections. For the most important expositions in this department of ophthalmology we are indebted to Von Graefe, who left to the world, among his richest contributions to the literature of science, extensive memoirs upon subjects connected with the ocular muscles, replete with learning and original research. Investigators from his time have been, in large measure, content to accept the results of his splendid genius as in the main conclusive, and since his death it cannot be said that any very striking advance has been made in this direction. But Graefe's observations were those of a pioneer. They were not exhaustive, indeed they were, in respect to the class of affections now under consideration, incomplete and confined mainly, it may be said almost exclusively, to a single anomaly among several, and that one, as it will be seen, not the one of greatest practical importance. In these muscular affections in which, with absence of equilibrium the ability to maintain binocular vision remains, there is a tendency on the part of the eyes to permit the visual lines to deviate from parallel directions. Graefe, with others, taught that when the ocular muscles are all accurately proportioned in respect to their dynamic conditions, and the performance of binocular vision is accompanied with the least expenditure of energy, the ocular muscles are to be regarded as in "equilibrium." The tests, however, which have been applied to the determination of the presence or absence of equilibrium have not in all cases been sufficiently trustworthy, and it is desirable in the beginning of this discussion to determine precisely what is indicated by the term equilibrium, and to establish definite means of ascertaining, by the most conclusive methods attainable, the true conditions of the muscles in this respect.

Graefe regarded the ability to direct the axes of the two eyes to the same point, at the usual distance of reading, without excessive effort, as a practical standard of equilibrium, and taught that this should be gained even at the expense of very great loss of equilibrium at greater distan-

ces. Thus, in operating for relief of "insufficiency of the interni," he was ready to induce very high degrees of "insufficiency of the externi," or even homonymous diplopia at a distance. As Graefe's operations were in large measure designed for the relief of "insufficiency of the interni," in cases of high grades of myopia, the great disadvantages of the loss of equilibrium at a distance were less pronounced than would have been the case under other circumstances. Such a standard of equilibrium should not be accepted. Equilibrium does not exist when comparatively easy fusion of images is gained at one point at the expense of difficulty or impossibility of fusion at another.

In equilibrium, the visual lines of the two eyes should be parallel when the force of the will in accommodatating or adjusting the eyes is removed—that is, when the minimum of nervous impulse is directed to the ocular muscles. Deviations from a given standard of equilibrium short of the loss of power of fusion of images have been known as "insufficiencies." The term has, however, been mostly applied to an inadequate converging power for the distance of reading or ordinary work, and it has often, even by Graefe, been employed in connection with low grades of actual strabismus.

In the conditions of absence of equilibrium now under consideration, and as they will be discussed in this paper, there is, in the act of vision, no actual turning of one visual line in a direction differing from that of the other when looking at a distant point. Indeed, in gazing directly forward at a distant object parallelism is supposed. There is, however, in these conditions, on the part of some one or more muscles, a tendency to disturb the balance; and should the nervous control be so removed as to permit of the consummation of this tendency, an actual deviation would result. Such irregular tendencies, then, may exist in as many directions as there are forces to induce irregular tension—that is, not only in as many directions as there are muscles to act, but in as many directions as the muscles may combine to act. In short, then, these tendencies may exist in all directions. Without stopping here to discuss

the question whether it is important to discover and to estimate the degree of all these deviations—a subject which will engage our attention further on,—we may here assume that all are important, and that no just appreciation of the conditions which induce asthenopic or kindred troubles can be acquired which does not take them all into account. It becomes necessary, then, to establish some method of investigating and of recording such anomalies.

So long as the increased tension upon the interni, in the act of reading, or in other continued work at a like distance, was regarded as the main, if not the only important factor in the causation of muscular fatigue, aside from accommodative lesions, the test of the dot and line, as suggested by Graefe for this condition, appeared to answer the requirements. This familiar test was made at reading distance, although Graefe counsels that, after having determined the degree of insufficiency for this distance, we should examine in the same way for greater distances. Without specifying the distances, he, in close relation to this part of the discussion, mentions his experience at abduction and adduction at a distance of six feet. This counsel, to determine the insufficiency at greater distances, judging from the literature of text-books, has been mainly disregarded, and indeed Graefe himself considered it of secondary, if not in most cases of little importance. The facts remain that in respect to this one test for a single condition there is not a well-established rule or custom. Even were complete uniformity observed in the examinations or records of this condition of the ocular muscles, this method is quite inadequate for the determination of several other conditions, and, as will be seen hereafter, extremely unreliable even for this one.

No just appreciation of the muscular balance can be arrived at while the accommodation is considerably exercised. Hence the principal determinations should be made at such distance as to render the accommodation practically relaxed, and while the determination of the inclination of the visual lines in the act of accommodation may be of importance, and may throw some light upon the false tenden-

cies, it should not be regarded as a method representing the presence of equilibrium or of the degree of deviation from it.

Elsewhere¹ I have discussed the manner in which one may discover these faulty conditions. In order that in what is to follow there may be no misunderstanding, that the conditions under which the investigation of these visual tendencies are to be made and the manner of making them may be definitely understood, I trust that I may be pardoned for restating in as brief a manner as possible what was there more fully discussed. The head being in the "primary" position and the ocular muscles relaxed, while ametropia, if existing, is corrected by appropriate glasses, the subject of examination directs the eyes at an object, preferably a lighted candle against a dark background, situated at the distance of twenty feet. Diplopia is then produced by a prism. First of all diplopia should be produced in the horizontal direction, in order to determine the relative tendencies of the visual lines in the vertical meridian. If the prism is first employed with its base up or down, and especially if it is held before the eye for some seconds, there will follow a partial adjustment of the visual axes to the new condition, and if then the prism is placed horizontally, this temporary adjustment may appear in the test which is about to be made. A very slight adjustment of this kind is of much less importance in the tests for the lateral relations. A prism sufficient to prevent fusion of images at the given distance, but not so strong as to cause a wide separation of the images, is to be placed with its base inward and exactly horizontal. If now the two images of the object looked at appear to be precisely in the same plane, no tendency of one visual line to rise above the other has been shown. If on the other hand the images appear not in the same plane, a prism should be placed before one eye with its base up or down, and of such grade as will bring the mounting line down or the depressed one up to the plane of the other. The degree of prism marks the

¹ *Archives d'Ophthalmologie* (Paris), Nov., 1886; *New York Medical Journal*, Dec. 8, 1886.

ascertained degree of tendency to deviate from the plane. For convenience in making this determination I have had made several pairs of spectacles containing, in each side, prisms of equal grade, 5° , 6° , and 7° each, with their bases in. The glasses are quite long and in the form of a parallelogram, in order that their exact position on the face may be accurately known. These spectacles are convenient in saving time and in assisting toward greater accuracy in the examination than is likely to be obtained by the use of the ordinary trial frame or from prisms held in the hand.

This test having been made with care, the prism is then placed before one eye with its base up or down. Graefe used a prism of 15° ; for his tests were made at near range, but one of 7° or even less will, in ordinary cases, induce diplopia, and permit of more accurate judgment of the relative position of the images on the part of the patient. Any deviation from the vertical line is to be measured by the prism which will bring the images in line, as suggested by Graefe. By turning the first prism a certain number of degrees until the correction is made, we may also, the grade of the prism and the degree of the turning being known, estimate the degree of deviation. By these two procedures information in two very important directions is obtained; but the absence of positive evidence of anomalous tendencies, as shown by these tests, does not by any means prove the presence of equilibrium, and other means must be tried. Here the method of producing abduction and adduction is to be resorted to, not, however, at six but at twenty feet.

An experience in many thousand examinations leads me to believe that the standard of normal abduction should be about 8° , and that of adduction at about 50° . In respect to this last, however, the ability to overcome prisms equal to 50° implies, in most cases, an ability indefinitely exceeding this, and many who at the first trial can accomplish only one half of this will, after two or three attempts on different days, succeed in uniting images with the full strength of the adducting prisms. On the other hand, while the failure to overcome at twenty feet a prism of 8° with its base in

should be regarded as suggesting an excess of energy over the others on the part of the interni, and while power to overcome a higher prism suggests a balance in the opposite direction, many cases occur in which the absence of ability to overcome a prism of 5° does not prove an inward tendency of the lines, nor does the blending with a prism of 10° or 12° prove a tendency outward. The ability to overcome a very strong prism with its base inward may be associated with actual converging strabismus, and the failure to overcome a comparatively weak one may be associated with an outward balance.

These results are to be compared with those already obtained by the diplopia tests when the prism is held vertically, but especially should they be considered in regard to any tendency of the visual axes to deviate in respect to the horizontal plane, for, as it will be seen, a very slight anomaly in this respect may modify the abducting or adducting power materially. In a like manner also, the ability to overcome a prism with its base up or down should be ascertained. Graefe declared his inability to overcome a prism of more than one degree in this direction at six feet, and states that, for nearly all those whom he tried, a prism of 2° was too strong. My own experience varies from this, for I have found that a very large proportion of the persons whom I have examined can overcome 2° or 3° at twenty feet, and I should place the average ability in cases in which no false tendencies exist in this direction at about 3° . It is not very uncommon to find persons who will overcome 9° or more in this direction. But it would appear to be of slight consequence whether the adjusting ability in this direction is rather more or less than 3° , if the power in one direction is equal to that in the other. An excess of power, however, leads to the suspicion that excessive demands arising from anomalous conditions have been imposed upon the muscles. The adjusting power is, in this respect, to be proved by placing the strongest prism which can be overcome before one and then the other eye in the same manner, or by reversing the prism before the same eye; for the effort at overcoming a prism with its base

down before one eye, is identical with that for uniting with its base up before the other. If we consider the results of the examination in the horizontal direction in relation to those in the vertical, we shall be able to form an opinion concerning the presence or absence of equilibrium, and, if manifest deviating tendencies exist, of the direction and extent of such tendencies. It is not, however, to be assumed that these indications are absolute. They are, as a rule, correct so far as they are positive, but they do not of necessity permit us to determine the absolute degree of deviating tendency. Here, as in hyperopia, a latent anomalous tendency may exist but, unlike hyperopia, we have here no means of ascertaining at a single examination the absolute departure from the ideal standard. Notwithstanding no proof may have been obtained by these trials, latent tendencies of great importance may exist. Our tests determine the manifest conditions only, and it is a safe rule to consider that the deviating tendencies are never less than are shown by our trials, but that they may greatly exceed that which we are able to demonstrate.

Having determined in this manner the approximate condition of muscular adjustment when no effort of accommodation is demanded, we may proceed to a similar examination at a near point. For convenience we may adopt the distance at which the majority of people hold the page when reading. Tests made at the distance of one half metre will sufficiently indicate the tendencies when the eyes are in accommodation for near work. Here prisms of greater angle than those employed for producing diplopia at a distance will be required, but the determinations may be made in the same general manner. Presbyopic persons should be supplied with reading-glasses in making this test, and the glasses for myopes should be such as are suited for the prescribed distance.

Terms by which we may express all the deviating tendencies which may be discovered in the manner indicated have been wanting. The imperfections of the nomenclature for ocular muscular anomalies have been discussed by myself in the articles already referred to, and a system of terms has

been suggested. While, in order to avoid misunderstanding, the terms already familiar will, to a certain extent, be employed in this discussion, those which I have proposed will be used as the standard, and without apology for the innovation beyond what I have expressed in the former papers. The signification of these terms is repeated here:

"I. Generic terms. *Orthophoria* (*ὀρθός*, right, *φóρος*, a tending): a tending of the visual lines in parallelism. *Heterophoria* (*ἕτερος*, different): a tending of these lines in some other way.

"II. Specific terms. Heterophoria may be divided into: (1) *esophoria*: a tending of the visual lines inward; (2) *exophoria*: a tending of the lines outward; (3) *hyperphoria* (right or left): a tending of the right or left visual line in a direction above its fellow.

"This term does not imply that the line to which it is referred is too high, but that it is higher than the other, without indicating which may be at fault.

"III. Compound terms. Tendencies in oblique directions may be expressed as *hyperesophoria*, a tending upward and inward; or *hyperexophoria*, a tending upward and outward. The designation 'right' or 'left' must be applied to these terms.

"In recording the respective elements of such compound expressions I have employed the sign \perp . For example, if it is desired to indicate that the right visual line tends above its fellow 3° , and that there is a tending inward of 4° , the facts are noted thus: Right hyperesophoria $3^\circ \perp 4^\circ$."

II.

HYPERPHORIA.

By hyperphoria is meant the condition of the ocular muscles in which, with a minimum of tension, a deviation of one visual line above the other would result. Habitual binocular vision is assumed, although we shall see that it is probable that in a considerable proportion of cases in which hyperphoria of more than a single degree exists, the tendency to diplopia is so great that the subjects of the

affection often surrender to it—a fact confirmed by the marked amblyopia often found associated with this muscular condition.

Among the varieties of heterophoria none exerts a more disturbing or injurious influence than hyperphoria. It is not only a condition giving rise in itself to great fatigue and perplexity, but it complicates and exaggerates all other faulty tendencies. When we recall the fact that with a fair adducting power one may overcome prisms of 50° with the base to the temples, and that with a good abducting ability a prism of 7° or 8° is easily overcome in the opposite direction, it will be apparent that muscles which do not ordinarily overcome more than a prism of three degrees, as is the case when the prism is placed with its base up and down, must be in a condition of great disadvantage when hyperphoria of one or two degrees exists. If we were to compare the relative nervous impulse demanded by the grade of the prism, which can be overcome in the different directions, then a deviating tendency of one visual line above the other (hyperphoria) of one degree would be equal to a deviating tendency outward (exophoria, insufficiency of the interni) of more than fifteen degrees. In other words, a faulty tendency of one or two degrees in the vertical direction falls little short of a diverging strabismus in importance. That this is actually nearly the relative importance of the two conditions appears evident from several considerations which arise from conditions found associated with hyperphoria. These conditions are local and remote. The local relate directly to the function of vision, to the adjustments of the eyes in the performance of the visual function, and to nervous disturbances of a functional or trophic nature in and immediately about the eyes.

The remote conditions relate to a great variety of disturbances of a nervous character in parts more or less removed from the eyes.

Hyperphoria of a low grade, as determined by a correcting prism, is very frequently attended by amblyopia. It is no unusual occurrence to find, in a case of hyperphoria which may be measured by a prism of 1° or 2° , vision of

only $\frac{3}{4}$ or even less, while the refractive conditions are not far removed from emmetropia, and the ophthalmoscope reveals either no pathological state or only a slight tendency to the hyperæmia about the disc which is characteristic of irritability of the eyes from muscular irregularities. The relative number of cases in which such defective visual power exists will, to one who has not well considered the subject, appear to be out of proportion to the muscular defect. The surprise will, however, give place to conviction if we bring clearly to mind the actual effects from the standpoint of physiological optics, of a very slight faulty tendency in the vertical direction. An actual deviation of a single degree would result in a separation of images at a distance of one half metre, approximately of 6.4 *mm*. A patient, then, with this amount of deviating tendency, who would bring the letters of the type in which this page is printed, even in contact, the lower border of the upper image touching the upper border of the lower, would require to exert a force upon the superior and inferior muscles greater than Graefe was able to exercise. If, however, by long practice, the muscles engaged in overcoming this fault acquire unusual strength, as is actually the case, still, when the tension has been continued for a considerable time, or when the general nervous tone is diminished from fatigue or ill health, an almost irresistible tendency to diplopia will occur. The remedy for the confusion thus induced is a renewal of the inordinate muscular tension or the suppression of the image of one of the eyes. This later really takes place, and the image suppressed is liable to be that of the eye in which greatest refractive anomaly is found, if a difference exists, or if the eyes are equally well adapted for clear vision the suppression occurs alternately. Hence, with a greater refractive anomaly in one eye, amblyopia will usually be found principally in the less perfectly constructed eye, while if the eyes are nearly or quite alike, the amblyopia will exist equally in the two eyes. Exceptions to this rule exist, especially in cases where, with myopia as the ametropic condition, the myopic eye is employed at the near point, while the more perfect eye is used for distant seeing.

The extent to which amblyopia exists in connection with hyperphoria is illustrated in the following tables. One hundred consecutive cases in which there existed hyperphoria, and in which no disease or injury of the eyes was found, and in which the refractive errors were not sufficient to account for any considerable defect of vision when correcting glasses were used, are included in the tables, excluding cases of high grades of refractive errors. The highest grade of astigmatism not exceeding 3.00 D, the highest of hyperopia not exceeding 4.00 D, and the highest of myopia not exceeding 5.00 D.

TABLE I.

| Refractive error. | 1.00 D or less. | More than 1.00 D; not exceeding 2.50 D. | More than 2.50 D to 4.00 D. | More than 4.00 D to 5.00 D. | Total. |
|-------------------|-----------------|---|-----------------------------|-----------------------------|--------|
| Emmetropia . | | | | | 45 |
| Myopia . . . | 9 | 19 | 7 | 7 | 42 |
| Hypermetropia | 37 | 24 | 12 | | 73 |
| Astigmatism . | 28 | 7 | 5 | | 40 |
| | 74 | 50 | 24 | 7 | 200 |

| Acuteness of vision. | Refractive error. | | | | | | Total. |
|----------------------|-------------------|------------|---|------------|---|------------|--------|
| | 1.00 D or less. | | More than 1.00 D; not exceeding 2.00 D. | | More than 2.50 D; not exceeding 5.00 D. | | |
| | Best eye. | Worst eye. | Best eye. | Worst eye. | Best eye. | Worst eye. | |
| 20 | 38 | 21 | 7 | 7 | 4 | 4 | 81 |
| 20 | 22 | 15 | 8 | 8 | 1 | 5 | 59 |
| 20 | 6 | 8 | 3 | 7 | 3 | 4 | 31 |
| 20 | 1 | 2 | 2 | 5 | 1 | 2 | 13 |
| 20 | 1 | 1 | 1 | 2 | 2 | 2 | 9 |
| 20 | | 3 | | | | 2 | 5 |
| 100 | | 1 | | | | 1 | 2 |
| 20 | | | | | | | |
| 200 | | | | | | | |
| Total | 68 | 51 | 21 | 29 | 11 | 20 | 200 |

In the first table the proportion of eyes affected with different grades of refractive errors is shown; in the second, the acuteness of vision according to the refractive condition.

The vision of the best- and worst-seeing eyes in each grade is given but for convenience, in the estimate of the comparative value of the best and worst, in all cases where vision is equal in the two eyes one is reckoned as best and the other worst. If anisometropia exists to the extent of bringing the refractive conditions of two eyes in different columns, the vision of one eye only is placed in each column.

From the above tables we obtain the following approximate results:

Average Vision of Best Eyes.

Sixty-eight with less than 1.00 D refractive error, $\frac{1}{2}\frac{6}{0}$.

Twenty-one with more than 1.00 D and less than 2.50 refractive error, $\frac{1}{2}\frac{3}{0}$.

Eleven with more than 2.50 D and less than 5.50 D refractive error, $\frac{1}{2}\frac{3}{0}$.

General average of vision of 100 best eyes, $\frac{2}{3}\frac{0}{0}$.

Average Vision of Worst Eyes.

Fifty-one with less than 1.00 D refractive error, $\frac{1}{2}\frac{4}{0}$.

Twenty-nine with more than 1.00 D and less than 2.50 D refractive error, $\frac{1}{2}\frac{2}{0}$.

Twenty with more than 2.50 D and less than 5.50 D refractive error, $\frac{1}{2}\frac{1}{0}$.

General average of vision of 100 worst eyes, $\frac{2}{3}\frac{0}{0}$.

It will be seen from the above table that defective vision is rather the rule than the exception in moderate degrees of hyperphoria. It is a fact that must have occurred to every experienced oculist, that in anisometropia a material difference in the visual power of the two eyes is exceedingly common. But it is also true that in anisometropia a difference in the form of the orbit is quite common, a fact which would tend to a failure of equilibrium in the length or strength of the motor muscles of the eyes. Experience

confirms this reasoning, and I have found that instances of even approximate balancing of the eye muscles in anisometropia is rather exceptional.

From the facts thus ascertained it becomes evident that amblyopia is not only very commonly associated with hyperphoria, but that it is not uncommonly a result of that anomalous condition.

A peculiar and interesting visual disturbance, related to yet differing from amblyopia, is the inability of the subject to see small objects clearly, although for larger objects, at the distance of some feet, the visual power is fair or even good. Thus, one may be able to read No. XXX., or even No. XX. of Snellen's scale, and may have no especial fault of accommodation, yet when No. I. is presented at the distance of one foot, the patient is quite unable to read. Small objects or characters are seen indistinctly or not at all. The fault in these cases appears to consist in an inability completely to fuse the images of the two eyes, while the separation is not sufficiently great to enable the patient to easily suppress one of them. This phenomenon is illustrated in the confusion which appears when one reads the word here doubly printed: *Accommodation*. If we cover with a card the lower range of type, the word is perfectly clear. A corresponding result may be effected in a considerable degree of hyperphoria by the mental suppression of the upper or lower rank of letters. If, however, the separation is less complete, as in this instance:

Accommodation we are quite unable to exclude either of the confusing ranks, as in the former experiment with the card, and the difficulty of a mental exclusion on the part of the subject of hyperphoria in this latter case is likewise greater than in one of more complete displacement. That only a comparatively small proportion of hyperphoric persons experience in marked degree this inability to see small objects well, is probably to be accounted for on the principle that in the great majority of instances the subject of hyperphoria is able either to fuse the images completely, or to displace them to such an extent as to enable a mental exclusion of one image to take place.

The conditions in hyperphoria relating to the adjustments of the eyes through the influence of their motor muscles are extremely interesting and important. The disturbing effects upon the lateral equilibrium is especially noticeable, and is a source of great perplexity to the oculist in his examinations of the muscular conditions. In hyperphoria the tests for lateral deviations are very often contradictory, and in a very considerable proportion of cases unsatisfactory. Unless the examiner is on his guard against the anomaly under consideration, he is liable to fall into grave errors of diagnosis and of practice. These errors are especially liable to occur if we rely for evidence for muscular balance upon the near test as suggested by Graefe. By such a trial we are, in moderate degrees of hyperphoria, likely to find extreme grades of "insufficiency of the interni," when in fact, if the test is made at a distance of twenty feet, the contrary condition is found. It is not an unusual occurrence with the existence of a single degree, or even less, of hyperphoria, to observe with actual esophoria of 2° or 3° (prism) an apparent exophoria in accommodation of 10° or even 15° . Such results illustrate forcibly the danger of relying upon the dot and line test, or upon any similar test at the near point, for determining the propriety of an operation for tenotomy of the externi. Indeed it will not be out of place to remark in the most emphatic manner that the test for "insufficiency" made at the near point should never be taken as a guide for an operation.

This principle of apparent contradiction is well illustrated in the following interesting case. A gentleman was found to have so strong a tendency of the visual axes to deviate inwards that at distances of twenty feet much difficulty was experienced in maintaining single vision. A relaxation of the force of the external recti muscles habitually resulted in homonymous diplopia. The insufficiency as measured by prisms was, however, not more than four degrees. On the contrary, if the gentleman held a pencil or his finger before him at the distance of fifteen or eighteen inches from his eyes, crossed diplopia occurred from "insufficiency of the interni." A pencil held at fifteen inches was doubled to such an extent



FIG. I.—The dotted lines shew the track of the wire in an unshortened lid. B D B the angle of cartilage whereby the lid is lifted and held in position.

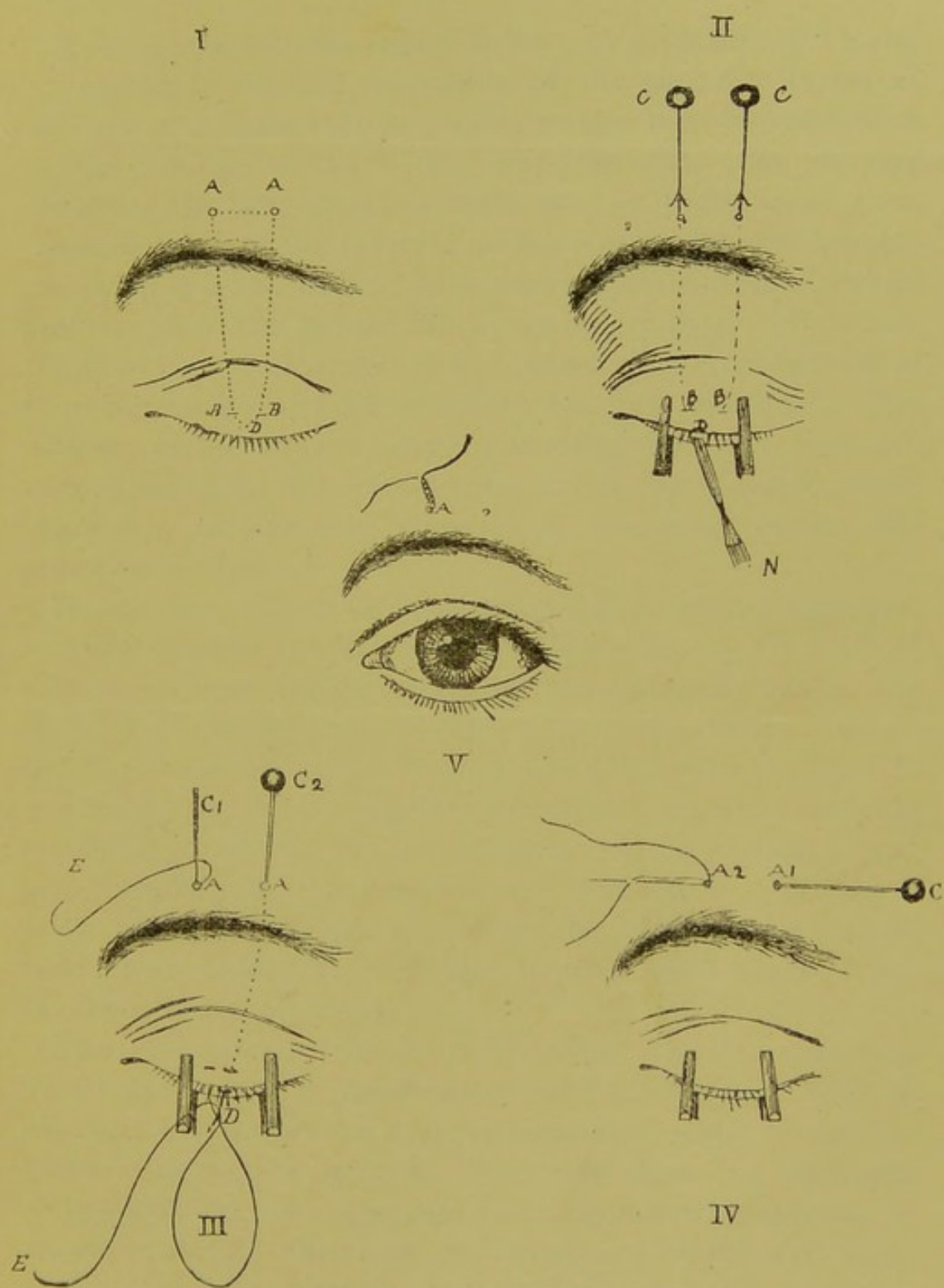
FIG. II.—Ptosis needles C C ready to pass through the split cartilage at B. N cutting needle opening cartilage for passage of needle point.

FIG. III.—C 1 needle point with wire end drawn into position from D.

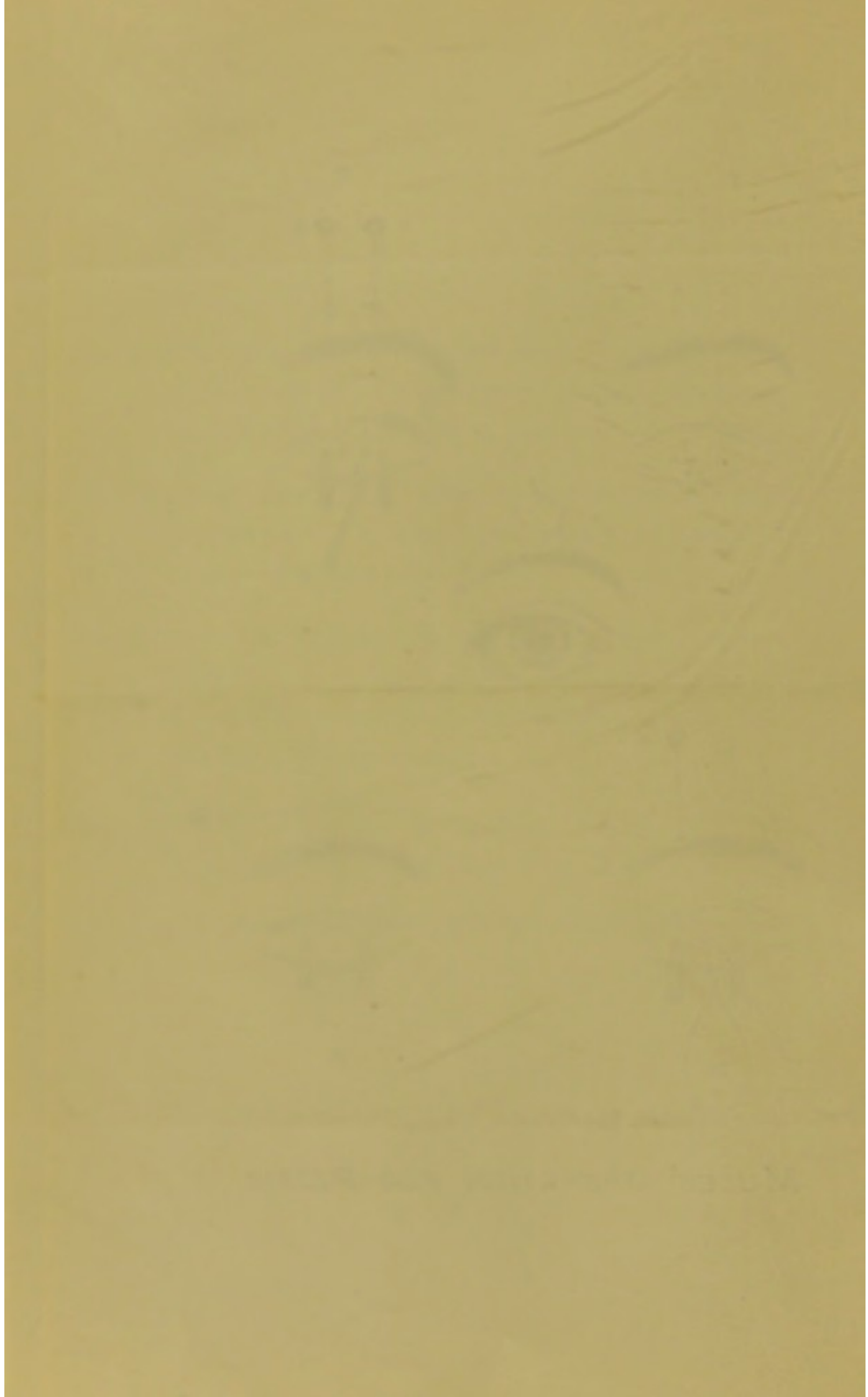
C 2 needle in position before drawing second wire end from lid edge to brow.

FIG. IV.—Wire end thrust across from A 1 to A 2, for shortening loop and twisting.

FIG. V.—Lid raised into position before cutting wire end.



MULES' OPERATION FOR PTOSIS



that the two images appeared about an inch separated. By the test of the dot and line the insufficiency was only about 6° or 7° .

This gentleman was found to have hyperphoria of 5° , and an operation for the relaxation of the superior rectus of one eye was made, followed a day or two later by relaxation of the inferior rectus of the opposite eye. On the day following the last operation there was no diplopia or even "insufficiency of the interni" at the near point, and binocular vision was maintained with ease at the distance. Several months later the gentleman again complained of double vision at near points, and it was found that hyperphoria of 2° in the same direction as before was now manifest. The inferior rectus of the upward tending eye was now advanced, bringing the visual axes to the same plane, when again the troublesome diplopia at the near points disappeared entirely.

A lady has crossed (heteronymous) and vertical diplopia, both for distant and near points. If a prism of 12° with its base down is placed before one of the eyes, she has at the distance of twenty feet "insufficiency of the externi" of 3° , but if no vertical prism is used, one of 4° with its base in will bring the two images to a vertical line, thus showing insufficiency of the externi with the strong vertical prism, and "insufficiency of the interni" without it. If now a prism of 6° with its base up before the right eye, or with its base down before the left eye, is used, the images of the two eyes blend perfectly.

Thus it appears that as the result of the deviating tendency upward an "insufficiency of the interni," both at near and distant points, may be simulated, while in fact the visual axes may be inward. Not only does the existence of hyperphoria often give rise to an apparent exophoria in accommodation when the real tendency of the eyes is inward, it also frequently presents the indications of exophoria at a distance while the abducting power is much restricted. We may, for instance, find exophoria 2° or 3° (prism), or even more, with a power of abduction not exceeding the apparent exophoria. Here is an evident contradiction, and

it may be, so long as the hyperphoria exists, impossible to determine whether our tests actually indicate an inward or an outward tendency of the visual lines, or neither of these conditions. It is because this important fact of the difference between the relation of the visual lines at a distance and those at near points has in many cases been overlooked, that surgeons of distinguished ability have sometimes performed tenotomy of the externi in cases of supposed "insufficiency of the interni" with the result of obtaining homonymous diplopia, without relief to the symptom of asthenopia. When once the hyperphoria is relieved by operation, we may hope for a more perfect determination of the condition of the lateral muscles. It is not proposed here to discuss the physiological reasons for the complications found in the muscular test when hyperphoria exists; this is a subject presenting many important difficulties, and the phenomena described can be fully explained only by actual experiments upon the muscles themselves. The evidences which may be found, however, that very marked "insufficiency of the externi" may exist when the accommodating and converging functions are at rest, and of "insufficiency of the interni," of possibly very high grade when these functions are exercised, illustrate the very unsatisfactory nature of the terms which have been so long employed in this connection, and appear to demonstrate that the use of terms having such opposite and misleading significations should be discontinued. The relation of myopia to muscular anomalies should occupy a prominent place in the discussion of the conditions dependent upon hyperphoria, but for reasons which will be given, that subject will be reserved for examination in the chapter on exophoria.

Another local affection caused by hyperphoria is hypersecretion of tears, by which the fluid fills the conjunctival sac and overflows the eyelids, causing much inconvenience and often disturbance of vision. These cases simulate the conditions found in obstruction of the nasal duct, and the absence of a general understanding of their nature is illustrated in the frequency with which such cases present them

selves for treatment, after having been subjected perhaps for many months to the process of probing the tear passages without any success in relieving the affection.

A branch of the fifth nerve supplies the lachrymal gland, and irritations to this nerve resulting from the efforts of correcting hyperphoria may result in so stimulating the gland as to induce the hypersecretion of tears, or it is quite possible that the pressure of the eyelids, which is often brought to bear to assist the ocular muscles in the performance of their duties, may expel the fluid from the gland in inordinate quantities.

Certain marked facial expressions and certain attitudes are characteristic, though not by any means constant in hyperphoria. Certain patients affected with this anomaly when looking indifferently, the eyes not specially directed to any object, will often present an appearance of moderate strabismus, more frequently diverging than converging. One of the eyes may even be observed to swing outward and then inward, giving a certain unsettled expression to the countenance. If, with even these strong indications of ocular deviations, tests for equilibrium are made, the result may be that either slight or even no evidence of lateral vicious tendency will be found. Involuntary convulsive contractions of the muscles of the face, giving rise to habitual distortion, constitute an important indication in some instances, of the efforts which are being made to overcome the effects of hyperphoria.

The habitual spasmodic closure of the lids of one eye should always direct the oculist's attention to the relations of the visual axes in the horizontal line. An effect upon the physiognomy not unfrequently observed is a rigid stare, the eyes being opened very wide, and all the facial muscles being apparently in a state of tension; associated with this peculiarity there is sometimes observed a tendency to snap the lids together forcibly and almost spasmodically.

The characteristic attitude of the head is even more striking and much more frequently observed. The head is carried toward the shoulder, usually to the side corresponding to the eye which tends below the other. This appears

at first thought to be quite inconsistent with the demands for relief. But when we remember that the object seen by the upward tending eye appears lower, and that seen by the downward tending eye appears higher, than the other, it becomes evident that by carrying the head toward the lowest tending eye the images of the two eyes are brought more directly into the horizontal line. In a certain proportion of these cases the contraction of the muscles of the neck becomes permanent, demanding for relief tenotomy of the tendons of the sterno-mastoid muscle ; but in much greater number the muscles of the neck will regain their equilibrium either speedily or after some time, when once the vicious ocular tendency is removed.

This peculiar carriage of the head is much more common than would be supposed by one who has not specially investigated the subject. To a close observer familiar with the fact, the false relations of the eye muscles is very often reached even before any of the technical ocular tests are made. Graefe spoke of the turning of the face to one side in cases of "insufficiency of the interni," in order to obtain relief to the lateral muscles or to assist in the mental exclusion of one image. The attitude of carrying the head toward one of the shoulders in hyperphoria is even more characteristic and much more common, and in this case serves to permit of more easy fusion by raising one image and depressing the other. As has been observed above, correction of the deviating tendency of the eyes is followed by an habitual erect carriage of the head.

The more remote results of hyperphoria are those common to anomalies of the ocular muscles, but with certain special characteristics. Neuralgia, neurasthenia, insomnia, chorea, and epilepsy are among the manifestations of this condition. Much more than esophoria or exophoria is hyperphoria inducive of vertigo and epilepsy. The nervous disturbance arising from this cause is more perplexing, both from the difficulty in overcoming it by ordinary effort, and from the complications arising from it in respect to the converging and diverging efforts, than moderate grades of deviating tendencies in the lateral direction. Hence,

nervous phenomena of a higher intensity are liable to result from this condition. The constitutional effects of hyperphoria are well shown in the following illustration :

This case was seen and treated at the Willard Asylum for the Insane. It is proper to remark that this institution is not designed for acute cases, or those in which there exists a reasonable prospect of recovery. It is a home for incurables, and the case here reported was one of chronic epileptic mania belonging to that class. The history is given as it was furnished by Dr. P. M. Wise, the superintendent, and Dr. H. E. Allison, the physician under whose immediate charge the patient was.

M. L., female, aged thirty-six. Insanity commenced seven years previous to the present record, but the patient has been subject to epilepsy for an unknown period, certainly longer than the period of insanity. About once a month she is taken with a series of epileptic seizures, varying from three to eight or more, and at these times is liable to become greatly excited, the degree of excitement depending apparently upon the number of convulsions. A period of great exaltation and frenzy follows, during which she is furious, sings wildly, and shouts at the top of her voice, and is exceedingly destructive and violent. The paroxysm may last several weeks. When it has subsided, she becomes orderly, neat, and industrious, and usually continues so until another series of convulsions occurs.

She was first seen by me July 31, 1886. Examination of the eyes showed hyperopia of moderate degree and right hyperphoria 4° (prism). Glasses for the correction of the hyperopia were furnished, and tenotomy of the right superior rectus was made, followed within a few days by a similar operation upon the left inferior rectus. This final operation was made August 22d. Bromides, which had been previously freely administered, were withdrawn July 31st. August 26th, four days after the last operation, a period of moderate excitement, very much less pronounced than usual, commenced, which lasted until Sept. 12th. On Jan. 2, 1887, five months from the beginning of the ocular treatment, Dr. Allison wrote concerning Miss L. : "She has not, thus far, had any attack of maniacal frenzy, and only one attack (that which is above mentioned) of excitement, which was not great. She says

she has not had any convulsions. . . . She is very much improved, and feels very grateful."

A single other instance will suffice here to illustrate the constitutional effects of hyperphoria :

A lady gave me the following history of her physical condition : She had been subject to asthenopia, severe headaches, vertigo, and backache during all her life, and had hardly experienced any relief during her waking hours. Fifteen years before my acquaintance with her she had been insane, and had been taken to an insane asylum, from which she was removed after a period of nearly one year, but only to return. She was not free from illusions for nine years. With the restoration of reason a new form of nervous manifestation was exhibited. Habitual and frequent paroxysms of vomiting have now continued during several years. The paroxysm commences by seeing every thing in confusion, followed by an indescribable nervous sensation in the back, and finally by violent retching and vomiting, which is greatly intensified when the lady opens her eyes. The paroxysms continue from two or three days to several weeks ; the last attack lasted six weeks.

She was found to have right hyperphoria 5° . She was furnished for a time with prismatic glasses, which established a nominal correction of hyperphoria, and after a few weeks tenotomy of the superior rectus of the right eye was made. The paroxysms of vomiting did not return, the lady was relieved of the distressing pain in the head, and soon after the tenotomy she expressed herself as feeling in every way better than she had done during the past twenty years. The lady was not seen during several months, but when finally she did present herself, she complained of suffering again from symptoms of asthenopia, but no more from the general nervous condition. Hyperphoria of 2° was found still to exist, which could not be discovered soon after the operation was made. Another tenotomy has since been made, which has been followed by relief to the asthenopic symptoms.

It will be seen that attending this muscular anomaly, headaches, pain in the back, vertigo, insanity, and habitual vomiting constitute prominent features which followed this lady from infancy ; one form of trouble succeeding another, and possibly replacing it for a time, but from some manifestation of which she was never free until she was relieved

from the necessity of a most difficult and perplexing ocular adjustment. With this release came relief from the whole train of nervous symptoms.

Treatment of Hyperphoria.

The treatment of hyperphoria is tenotomy. If the patient is unwilling to submit to a radical relief, or if the surgeon hesitates to perform the operation, if complicating circumstances render such an operation inadvisable, other means may be resorted to. The use of a prism, with its base up or down, is indicated under such circumstances. Let it be remembered that while glasses are of inestimable value, they are still inconvenient and often extremely so; that with the best art of the optician, glasses detract from the symmetry and expression of the face, a fact of much importance to females at least; and finally, that in the conditions of muscular deviations, they neither cure nor afford as complete temporary relief as a removal of the actual defect. Indeed, it is not uncommon for one having hyperphoria of 1° or 2° to suffer much pain in or about the eyes while wearing a correcting prism, but to experience almost immediate and complete relief from all the symptoms caused by the mal-adjustment of the eyes, as soon as tenotomy is performed. Glasses are like crutches, desirable when defects which render them useful cannot be removed. A special disadvantage of a very weak prismatic glass is the fact that it reflects a false image of every strongly illuminated object, seen at some distance, just above or just below the true image. This false image is often extremely annoying.

The daily exercise, continued through two or three weeks, of overcoming prisms placed vertically before the eyes alternately, with the bases in the same direction or before the same eye with the prism reversed, may tend to give the muscles greater vigor, and hence to enhance their ability to endure the difficulty. The duration of the exercise should not exceed three to five minutes at a time.

If tenotomy is performed, the surgeon must choose between relieving the tension of the superior rectus of one or

the inferior rectus of the other eye. If it is evident that the defect can be located in one or the other muscle, of course his treatment should be directed accordingly. This is possible in a very considerable proportion of cases. The appearance of the eyes, when the patient's view is directed indifferently in space, will often aid in forming a correct judgment. The fact that, ametropia being corrected, the vision of one eye is less than that of the other, is a strong indication that this is the deviating eye.

If it is impossible, as in a certain proportion of instances it appears to be, to determine to which of the eyes the anomalous tendency is to be attributed, we are left to select upon more general principles the one to be subjected to the tenotomy. The inferior recti are those which possess the greatest power, and therefore a slight advantage taken from one of these in favor of the weaker muscle will, other circumstances being equal, cause, if possible, less change in the motile functions of the muscles than in the opposite case. If the hyperphoria is of considerable grade, it is better, unless there are very positive indications that the fault lies in a special muscle, to gain the relief by relaxing both the superior rectus of one eye and the inferior of the other. By this procedure, no practical restriction results to the movements of either eye in the vertical direction.

The method of performing tenotomy in these cases of deviating tendencies less than strabismus, has been described by me some years since.¹ Since that time I have found it advisable to modify the procedure somewhat, rendering the operation more simple and the results more satisfactory. As now performed, the eyelids being retracted, a fold of the conjunctiva is seized by a fine but rather rigid pair of mouse-tooth forceps, parallel with the course of the muscle and exactly over its insertion. With a pair of small narrow-bladed scissors, having blunt but very perfectly cutting points, a transverse incision is then made through the membrane, exactly corresponding to the line of insertion of the tendon. The conjunctival opening thus made

¹ "Irritation oculo-névralé" : Mémoire de l'Acad. Royale de Méd., Belgium, 1883.

should not exceed in extent one fourth of an inch. With the forceps now pressing the outer cut edge of the conjunctiva slightly backward toward the course of the tendon, the latter is seized behind but very near its insertion. The distance may depend upon the freedom with which the intended section of the tendon is to be made. But in hyperphoria or in slight relaxations of the lateral muscles, a distance barely sufficient to allow a small part of the tendon to be raised from the sclera is all that should be allowed. Making some tension now with the forceps, the points of the scissors are directed against the central portion of the tendinous insertion and toward the sclera, when a small opening is made dividing the centre of the tendinous expansion exactly on the sclera. The small opening is now to be enlarged by careful snips of the scissors toward each border, keeping more carefully on the sclera as the border of the tendon is approached. As the section of the tendon is carried toward the borders, the outer blade of the scissors passes beneath the conjunctiva. If the relaxation of the tendon is to be slight, the extreme outer fibres of the tendon are to be preserved untouched; but if a considerable effect is desired, these fibres can be entirely severed, *provided that the reflection of the capsule of Tenon upon the tendon is not disturbed*. By means of the capsule acting as an auxiliary attachment, the tendon is held in position, but is allowed to fall back slightly while maintaining its relation to the eyeball. In this respect, and in preserving the outer tendinous fibres, this operation differs radically from the ordinary operation for strabismus, and from any operation which has been proposed for so-called "partial tenotomy" of the recti muscles.

The judgment of the operator must determine the extent to which the division should be carried, but should it be found that too little has been accomplished, the section can be extended. In doing this, the use of a very fine hook may be advisable. For this purpose a hook very much smaller and more delicate than the ordinary tenotomy hook should be employed. Its rounded point is carried under the remaining border of the tendon with great care,

to prevent hemorrhage or unnecessary disturbance of the connective tissues; the extension being made toward one and then toward the other border, as the demand for further relaxation may require. When the remaining band of fibres is made tense by the hook it is slightly elevated from the sclera, when the fine-pointed scissors are introduced beneath the conjunctiva, and the necessary extension of the wound is made with extreme caution not to divide the capsular attachment. The conjunctival suture should in no case be employed.

All bandaging of the eye or covers of any description are not only needless but mischievous. Indeed, if permitted to digress from the subject at issue, I would express my unqualified disapproval of bandages in nearly all operations about the eyes. During many years I have abstained almost entirely from the use of bandages in ophthalmic surgery, and know of no reason to regret this course. Bandages are promoters of heat, filth, and septicism. They have no possible advantage, and should, I believe, go out of fashion in ophthalmic operations. My own patients are permitted to return at once from the operating-room to their homes without regard to weather or the distance to be travelled. Many of them return on the day of the operation to their ordinary business.

In respect to the results of tenotomy for hyperphoria there would appear to be nothing in the range of surgery more satisfactory or certain. My first operations for the correction of a tendency of the visual lines to deviate in the vertical direction, and in which no vertical strabismus existed, were made in 1875. Very many were made in each succeeding year, but it was not, however, until during the past two years that the operation in my hands became as uniformly successful as could be desired. Now, with the procedure which has been described above, there is a great measure of certainty of success. During the year 1886 I performed tenotomy for the relief of hyperphoria one hundred and nine times in eighty-eight cases. The result in nearly every instance was, when the patient was last examined, a relief either partial or complete to the hyper-

phoria. In some instances in which, soon after tenotomy, no hyperphoria could be discovered, a partial return to the original condition has been found, and quite possibly this may be true of some who have not been seen since within a month or two of the operations. Of those in which a partial but incomplete relief to the hyperphoria has been accomplished, some are still under observation for treatment. Among these are two cases in which tenotomy of both externi has been performed by prominent oculists, in each instance leaving the patient with homonymous diplopia and pronounced hyperphoria, unless, in one instance, the vertical deviation should be regarded as an original vertical strabismus. In both instances nearly complete correction has been accomplished, and there seems no doubt that in the end equilibrium in all respects will be established.

Of the cases which have been stated to be correct when last seen, it may be repeated that it is possible that, at a future time, hyperphoria of a certain degree may become manifest. This happens in a proportion of cases after some weeks or months, and it is not safe to assume that no hyperphoria exists until many months after the operation.

In respect to the results of treatment of hyperphoria it is my purpose only to say here that the relief in uncomplicated cases is of the most marked, not to say surprising, character. Many patients who, from this cause, have suffered from distressing affections during many years recover, when this source of irritation is removed, with astonishing rapidity.

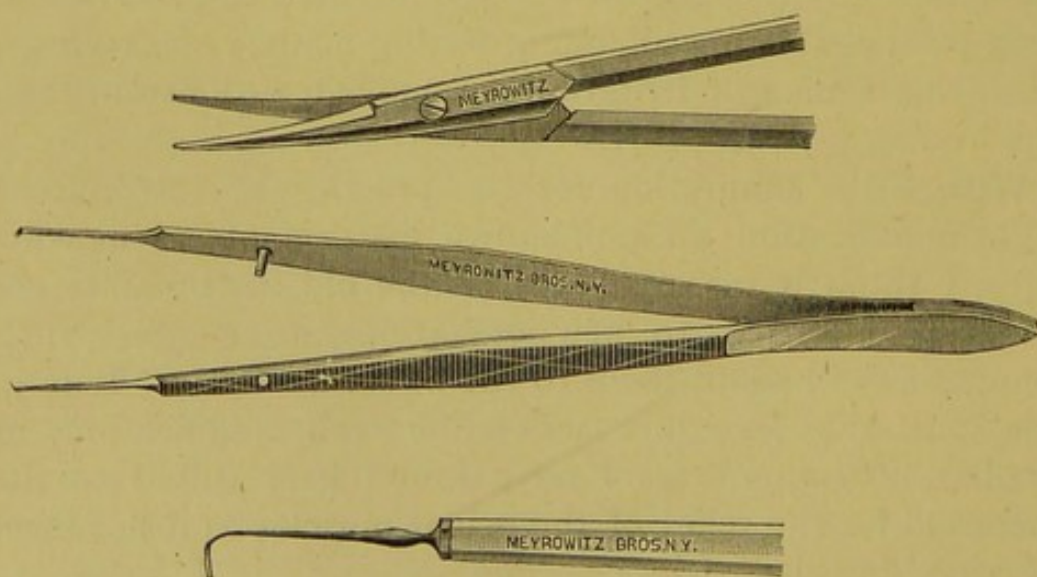
With little admiration for the practice of introducing slight modifications of well-known instruments as new designs, I think it reasonable, when the old instruments are evidently unsuited to new operations, to suggest such changes as will adapt them to the new conditions. It is in this spirit that I venture to describe such modifications of familiar instruments as I have found best suited to the operation for the relief of the ocular muscles as it has been described in this article.

The scissors have narrow yet strong blades, cutting perfectly at the points, which are blunt, in order that they may

not endanger the sclera. The blade is scarcely wider at the distance of half an inch from the point than at the point. This form permits the narrow blade to be insinuated between the conjunctiva and the insertion of the tendon with the least possible disturbance. I have found much difficulty in having scissors of this description made which, with the very narrow blades, should possess sufficient strength and perfect cutting qualities at the points. After several trials, Messrs. Meyrowitz Brothers have succeeded in producing an instrument combining these requirements.

The toothed forceps are so constructed as to combine much strength with delicacy at the working extremity. The branches are one fourth of an inch broad at their widest part, and taper but slightly until within one half inch from the toothed extremity, where they are suddenly contracted to a very narrow shaft, as fine as the most delicate iris forceps.

The hook is also quite delicate. From the stem, an inch in length, the hook extends by a short curve, at nearly a right angle, to the distance of three sixteenths of an inch. It is rounded and slightly probe-pointed at its extremity. The diameter of the hook and of the principal part of the stem is a little less than 0.5 mm, or of the size of No. 25 of Brown & Sharp's wire gauge.



THE ANOMALIES OF THE OCULAR MUSCLES.

BY DR. GEORGE T. STEVENS, NEW YORK.

SECOND PAPER.

III.—DIFFERENTIAL CHARACTERISTICS OF HETEROPHORIA AND STRABISMUS.

IN order to arrive at a clear and exact understanding of the nature, importance, and management of the condition to be discussed in this paper we are to keep strictly in mind the difference between heterophoria and strabismus. To this end we may with advantage recall what has already been stated in the preceding paper in respect to the differential characteristics of the two conditions.

In the first of the two classes, heterophoria, binocular vision is habitually maintained but by the expenditure of a greater amount of force than is demanded in the perfect equilibrium of the ocular muscles. In the second class, strabismus, there is habitual diplopia, conscious or unconscious. It is true that, in certain cases of strabismus, fusion of images is possible for brief periods of time and under favorable circumstances, and it is also true that in conditions of heterophoria the tension upon the adjusting muscles is not always exercised to the extent of effecting a perfect and continuous blending of images. Nevertheless the fact of habitual ability or failure to maintain binocular vision should constitute a dividing line between strabismic and non-strabismic affections of the ocular muscles. It is to be admitted that in the general literature of "insufficiencies" the dividing line has not been sharply drawn nor

carefully observed. Indeed the term "insufficiency" has, by some writers, been loosely, not to say indiscriminately, used in speaking of well defined strabismic cases. Strabismus may result from insufficiency of certain muscles, but it is to be remembered that an "insufficiency" is not necessarily a strabismus. If these terms may be used in a convertible manner, it is only another reason for the introduction of terms having more precise signification.

Graefe¹ says: "The expression 'strabismus' has a symptomatic signification. It means the inability to unite both visual axes at the same fixed point lying in the common field of vision." And Donders² says: "In strabismus the visual lines do not cross one another in the point it is desired to observe." On the other hand 'insufficiencies,' while they are conditions consistent with binocular vision, may, under certain circumstances, become 'relative strabismus' or strabismus only at certain near points. Thus Donders³ assumes that convergence should occur at 2.5 inches in front of the eyes. Hence should the patient have myopia more than $\frac{1}{2.5}$ there will of necessity result diverging strabismus in reading. Of relative strabismus we shall have more to say in future. In this connection it is only necessary to remind the reader that it is not to be confounded with the more general term strabismus, or absolute strabismus. It becomes, first of all, desirable to find, if possible, some at least approximate indications of the limit of division between the conditions heterophoria and strabismus, or, if I may be permitted a still further extension of terms, between heterophoria and heterotropia. (*Φόρος* a tending; *τροπος* a turning). Such indications of limitation become necessary if we would express exact meaning by the use of our terms. It is needless to say that if slight cases of strabismus are promiscuously classed with heterophoria our observations and records respecting the two conditions must, necessarily, be imperfect and unsatisfactory.

The determination of the existence or absence of habit-

¹ " *Archive f. Ophthalmol.*, iii., i., p. 177.

² " *Accommodation and Refraction of the Eye*," p. 291.

³ *Ibid.*, p. 405.

ual binocular vision is not always devoid of difficulties. In a very large proportion of strabismics the subjects are totally unconscious of double vision, and in another large proportion they are habitually, but not constantly, unconscious. In many strabismic cases the most patient and persistent efforts on the part of the surgeon, perhaps continued through interviews on several days, are required in order to enable the patient to obtain consciousness of diplopia under any circumstances. It is evident, then, that the mere statement of a patient that he does not see double has little value in this connection.

We are, then, to find the means of ascertaining the fact of the presence of diplopia. For this purpose the methods long known to the profession may be, in nearly every case, successfully employed. I shall not here attempt to introduce new methods for reaching this end, but shall suggest some new interpretations of known methods, and endeavor to impress the necessity of a more thorough and systematic employment of those methods than has been indicated by published observations heretofore.

In certain instances in which the deviation of the visual lines is very considerable, yet not sufficient to be manifest to the observer, we may detect the fact of diplopia by the cover test. Unless this test is made with much care it may prove of very little value even in cases of pronounced deviation. While the patient fixes the gaze steadily for a minute or two upon a small object situated at twenty feet distance in the median line, the examiner, seated in such a manner as to obtain a perfect view of the eye to be observed, quickly slips a small card in front of the other eye. If the observed eye is the deviating one, a very slight and quick readjustment of this eye may be seen. This slight movement must not be confounded with a little twitch of the lids which may be seen in some nervous patients at the sudden approach of an object near the eye. Much greater care in observation must be observed than that which is required when, in a case of well marked squint, one places a cover before one eye in order to make a rude estimate of the number of lines of deviation. In a

case of steady binocular vision there will be no readjustment of the eyes when one is thus suddenly covered. This is not the well-known test of introducing a cover to observe whether one eye after a moment deviates outward as in insufficiency of the interni. The test, however, is a gross one, and can only be of service in cases of a considerable degree of deviation. It may be urged that in case of a marked tendency on the part of the visual lines to deviate but with power to maintain binocular vision, the tension upon the various eye-muscles would be different when both eyes are directed to the object from the condition when one eye is covered, and that under such circumstances a readjustment of muscular tension would be made when the cover is interposed before either eye. However correct this line of argument may be, I have not found it verified in practice. In cases in which I am able to detect minute adjustments of this sort, I have almost invariably been able to demonstrate double vision by other means. Hence, while this is a rude test for diplopia, it may, in a certain proportion of cases, be a valuable one.

2 A very large proportion of those who have habitual unconscious diplopia with such moderate deviations of the eyes as to be scarcely noticed by the observer, will recognize the double images when a prism is introduced in such a manner as to change the relative position of the images, even although it may be in the direction of correcting the diplopia or by slightly elevating or depressing one image. Thus one with unconscious homonymous diplopia may be able instantly to appreciate the position of the two images if the diplopia is partly corrected by a prism, or if one of them is raised above the other by a weak prism with its base down. Experience and judgment will be required to enable one to determine how far the prism is instrumental in inducing and how far in revealing diplopia. The method may prove more valuable in enabling the patient to learn the existence of double images under any circumstances than of determining their habitual presence.

By the ordinary use of the prism which shall remove the images farther from their habitual relation, we have another means of forming a judgment respecting diplopia.

If with a prism, with its base in, we cause conscious diplopia in the manner already described for detection of hyperphoria, we may determine the manifest deviating tendency from the horizontal plane. If now there were an absolute and uniform degree of such manifest tendency within which habitual blending of images could be assumed and beyond which diplopia could be confidently expected, it would be comparatively easy to settle the question of single or double vision in the vertical direction. I know of no such absolute line of demarkation. Nevertheless we may make some approximation toward a line of limitation. In the orthophoric state the eyes are able to unite images when a prism of 2° to 3° is introduced with its base up or down before one of the eyes. The power to go beyond this is very rare in cases of well-balanced eyes. This, then, marks, approximately, the limit of uniting images in this direction in such a condition. But in hyperphoria, the habitual effort on the part of the patient to force the eyes into proper relations will so develop the strength of the muscles engaged as to enable one to maintain single vision with a deviating tendency of rather more than this. Beyond a manifest deviating tendency of 3° or 4° in this direction,¹ then, we may reasonably expect that the ability to maintain single vision continuously is lost; especially may we infer this if we find associated with this tendency an important deviating tendency in the lateral direction. Thus one who would manifest at twenty feet a tendency of one visual line above the other of more than 3° or 4° and of the lines outward of, say from 6° to 10° , would, with scarcely a doubt, be unable to maintain single vision, although such a person might be able to obtain it for a brief period at a time. I have not met with any case in which, with diplopia under the influence of a horizontal prism, the images deviated from the horizontal plane more than 5° , habitual binocular vision has been maintained. To speak of hyperphoria, or non-strabismic "insufficiency of the inferior recti" of 10° to 15° , is, without doubt

¹ This is not to be confounded with sursumduction, which may reach 9° or more in myopia.

to employ such terms in an extravagant and irrational manner.¹

In a similar manner, if the deviating tendency in the lateral direction is more than the usual ability of the muscles to overcome in the direction opposite to the tendency, a presumption exists that binocular vision is not habitually maintained. The usual power of the abducting muscles in orthophoria is measured by a prism of about 8° or possibly 9° . A deviating tendency of considerably more than this would be inconsistent with single vision, except by the development of the strength of the abducting muscles beyond the physiological standard. Making due allowances for this, it would certainly demand an inordinate and, in the great majority of instances, impossible tension on the part of those muscles to maintain continuous fusion of the images in any case in which the deviating tendency inward should be shown to exceed the usual abducting power. Should it be found in an individual case that with a deviating tendency inwards of rather more than 8° , as shown by a prism with its base down, there should exist an unusual degree of abducting power, the eyes might ordinarily be adjusted for single vision. If, on the other hand, the abducting power should be found to be rather less than the usual standard, making due allowances for all collateral influences, it would be reasonable to assume that binocular vision cannot in such a case be regularly maintained. The proportional power of holding binocular vision at a distance in the deviating tendency outward is less than in the opposite direction; for whereas the fusion-power of a patient with a tendency of the visual lines inward may be equal to or slightly in excess of the usual power of abduction, one with a tendency of the lines outward will see double, at a distance, with a deviating tendency of much less than the

¹ Reports of cases of non-strabismic "insufficiencies" of the superior or inferior recti, for which the patients were required to wear prisms of 12° or 15° or even 20° with the bases up or down, are but grotesque illustrations of prevailing misconceptions in respect to the extent to which "insufficiencies" can exist before reaching the point of strabismus.

Again, in respect to the terms in use: If the ordinary power of the inferior rectus is sufficient to overcome momentarily a prism of 3° , the employment of the term "insufficient" to one which is supposed to habitually overcome a defect equal to 20° prism is evidently an inconsistency.

usual adducting force as measured by prisms. In orthophoria, with or without a little practice, most persons will overcome prisms with their bases out equal to about 50° . But a deviating tendency outward of much less than one half of this amount will be associated with an inability to hold images single during any considerable period of time. Making allowances for rare exceptional cases, my observations have led me to believe that a deviating tendency of 8° or more (at 20 feet) is inconsistent with single seeing. If, in an individual instance, the tendency of the lines is to deviate both in the vertical and in the lateral direction, the task of uniting the lines at the point to be observed becomes still greater. It happens, more frequently than otherwise, that a manifest deviating tendency outward of more than 6° or 20 feet is associated with inability to hold continuous union of the visual lines at that distance and much less at nearer points.

A third method of detecting habitual failure to maintain binocular vision, is by so reversing the ordinary experiences ³ of the visual sense as to bring into consciousness the existence of the extra images which have become by long practice mentally suppressed. This may be accomplished by the well-known device of introducing in front of one of the eyes a glass whose color shall be in strong contrast with the object upon which the gaze is directed. We may use a lighted candle placed at the distance of 20 feet, or more, from the patient, and at which he gazes, in a darkened room, or against a darkened surface. If diplopia exists, it may be manifested when a red glass is placed before one of the eyes. The fact that it is not manifested does not of necessity show that there is single vision, for the habit of a lifetime of suppressing one image may be too strong to be thus easily overcome. In a great many instances of inveterate squint, the difficulty of inducing the patient to recognize double images in this manner is extremely great. It often requires great patience and persistent effort, continued through many interviews on successive days, with the assistance of considerable ingenuity on the part of the surgeon in throwing the image in various directions by

means of prisms while the red glass is maintained in position, before a confession of double images can be obtained. Success will always crown persistent and intelligent effort. When once the patient has learned to apprehend the sensation of double images, little trouble will in general thereafter be experienced in locating them.

The presence of double images at this distance as shown by the colored glass is presumptive of habitual diplopia. Nevertheless, it may be urged that by giving the images different colors there is a modification of the instinctive demand for binocular vision, and the tension is so relaxed as to allow the images to separate. We are then to inquire to what extent this principle may be true. Observations conducted during several years and on a great number of cases have shown that the ability to maintain binocular vision, while a red glass is before one of the eyes, is less ordinarily than in its absence. How much less we will proceed to inquire. If one who has the ability to overcome a prism of 8° , with its base in, places a plain red glass before one of the eyes, his power of abduction will usually reach only 7° . If his power of adduction without the red glass is 50° , he will lose with its presence about the same proportion of his adducting power and will be able to adduct usually not more than about 45° . It thus appears that the influence of the red glass in orthophoria may be rudely estimated as being equal to about one eighth of the abducting or the adducting power. In examinations of those in whom heterophoria exists, the rule appears to hold good. It is to be seen, therefore, that the influence of the red glass in manifesting diplopia is, except within very narrow limits, entirely in the direction of revealing that which exists, rather than permitting diplopia to occur which would otherwise be avoided. Experience leads me to believe that a vertical deviation of a single degree as shown by a red glass is more than a patient will ordinarily overcome without it, and that habitual double vision is the rule when diplopia, as shown with a red glass which demands a prism of more than 1° or 2° for its correction, is found in the lateral direction. Indeed, diplopia with a red glass indicates the extreme limit of single vision without it. It is

to be remembered that in such an examination the patient is on the alert and is making his best efforts at fusion of images. If this statement should appear extreme, I believe it would not so appear after careful examination of the subject. I have found that patients having diplopia with a red glass corrected by a prism of 1° or 2° , will, after their attention has been repeatedly drawn to the phenomenon, become conscious that this is the habitual condition under ordinary circumstances. They may be able to unite images momentarily, but ordinarily the two images are not united. We may summarize these three methods of detecting the presence of habitual diplopia which appear to be most useful as follows:

1. The gaze of the two eyes being directed upon a distant object, the presence of diplopia is shown when the line of vision of one eye being suddenly interrupted by the interposition of a screen, the other eye is seen to make a movement for readjustment.

2. When conscious diplopia is caused by a prism, if the manifest deviating tendency in the vertical direction exceeds 4° , diplopia may be suspected, and the suspicion is made almost a certainty if combined with this there is a lateral deviating tendency of as much as 6° . If the deviating tendency in the lateral direction inward is shown to be more than 10° , or outward more than 8° , it is probable that binocular vision is not maintained.

3. If with a red glass before one eye diplopia is shown in the vertical direction, habitual strabismus exists. If diplopia is shown in a lateral direction strabismus is indicated if a prism of more than 1° or 2° is required to unite the images.

It will thus appear that while we have no absolute boundary between heterophoria and strabismus an approximate limitation may at least be found, and by patient investigation in individual cases we shall be able to make a practical diagnosis between the two conditions. It will hardly be exaggerating to say that diplopia as shown under the influence of a red glass may under almost any circumstances, be regarded as an indication that binocular vision, if obtained

at all, is not habitually maintained. This is perhaps the most practical line of division between strabismus and heterophoria, but it is one often very difficult to find.

I have already¹ called attention to the methods of proceeding in recognizing and treating one of the forms of deviating tendency less than strabismus, hyperphoria. I shall now direct attention to the second in importance, esophoria.

For determining heterophoria, especially hyperphoria, exactitude in the methods of making examinations is of greatest importance. With the view of securing accuracy and of saving time I have devised a phorometer which is here shown.

The instrument consists of the standard A, supported by a tripod. The standard is freely extensible, permitting a ready adjustment for differences in stature of patients. The arm B is grooved, and allows the carriers C and D to rest securely, to slide freely from end to end of the arm, or to be removed at will. At E a spirit-level is attached to the arm, by means of which the horizontal position of the arm can be determined. The semicircular piece at the head of the arm is spirally toothed and is acted upon by the endless screw at F, which imparts to the arm an upward and downward elbow movement. The semicircle is graduated in degrees, and a fine pointer indicates the extent of motion imparted by the screw. By means of the lever G, the screw can be unlocked, allowing the arm to fall to the side of the standard. Of the two prism-carriers one carries two prisms placed horizontal, with their bases in, and of sufficient strength to induce homonymous diplopia. The prism D is placed with its base down and is used for determining lateral tendencies. The rod H carries a tablet I, on one side of which is a small cross and on the other side another cross somewhat larger. The tablet is reversible, and the crosses are used as objects in determining the tendencies in accommodation. The tablet is, when brought into position, one half metre in front of the prism; but by means of a fixation screw it can be brought nearer if desired.

When not in use the rod is parallel with the arm. As has been intimated elsewhere, in the determination of the tenden-

¹ ARCH. OF OPHTHALMOLOGY, vol. xvi., 2, p. 115.

cies of the visual lines much freedom may be given to the position of the head without material effect upon the position of the images, provided the prisms are independent of

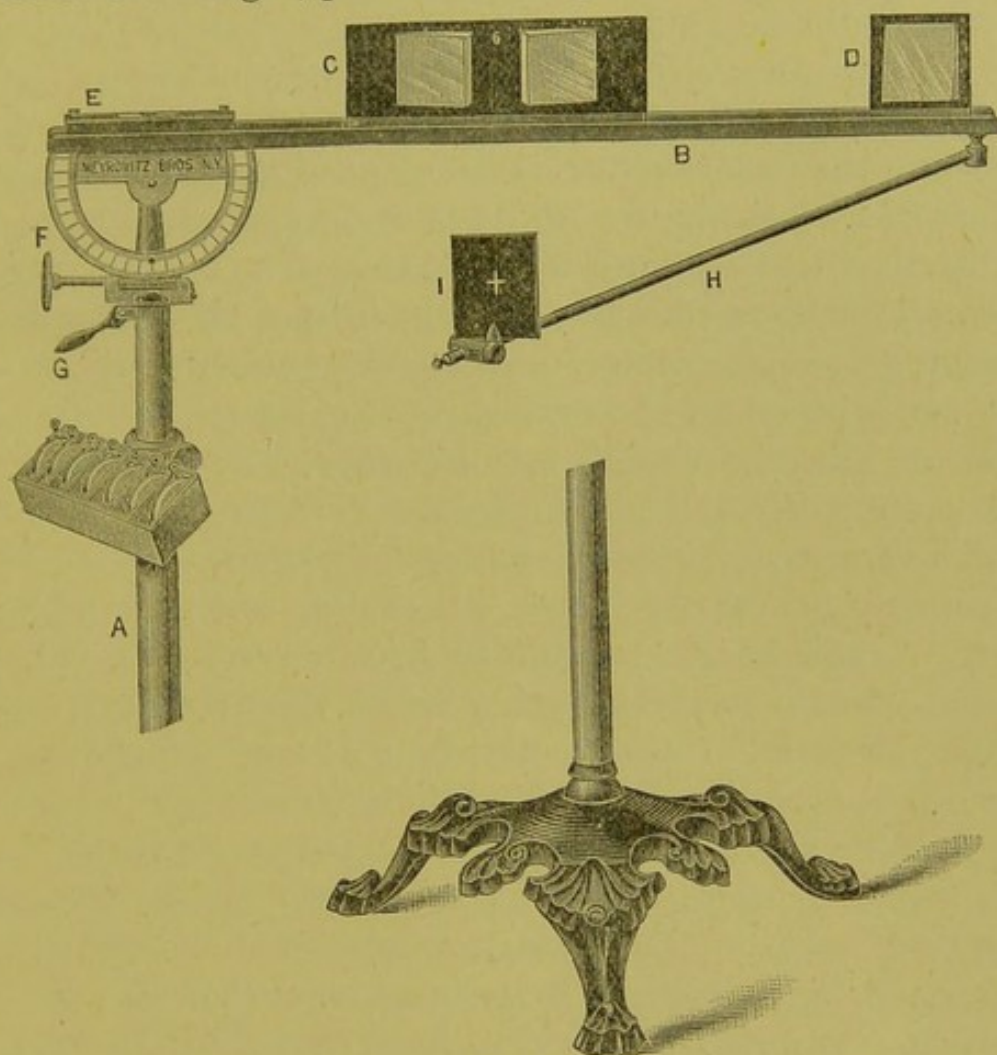


FIG. 1.

the head and somewhat removed from the eyes. This does not hold good in every case, but the exceptions are somewhat rare, and the presence of the exceptional condition can be quickly ascertained.



FIG. 2.

Fig. 2 represents a pair of revolving disks in a carrier adapted to the phorometer; each disk consisting of six prisms with the bases in. The two openings permit the two eyes to see from behind. By pressing upon the milled edge of either disk, prisms of different strength can be brought before the openings. The numerals in the figure show the strength of the various

prisms. This little device I find very convenient and time-saving in the determination of the power of abduction. A series of prisms for adduction is similarly constructed.

IV.—ESOPHORIA.

The method of determining esophoria has been already shown in the former paper. The prism of about 6° is placed before one of the eyes with its base downward or upward, and the patient's gaze is directed toward a lighted candle situated in the median line at the distance of twenty feet. Should the double images now appear exactly in the vertical line, no tendency to deviate in the lateral direction is shown. The test should not, however, be abandoned at this point. While maintaining the vertical prism in position, a very weak prism may now be placed with its base alternately in and out before either eye, when the relation of the double images is again to be observed. Should the images remain in the vertical relation the strongest prism which can thus be interposed without causing a deviation of one or the other image is placed before one of the eyes and the result is recorded as esophoria or exophoria as the case may be of $0^\circ < n^\circ$. If with the prism, its base down, the images deviate homonymously, esophoria is indicated; exophoria being shown by heteronymous deviation. If, for instance, the prism is placed with its base down before the right eye, the higher image will be that of the right eye. If this image is at the right of the lower one, there is homonymous deviation showing esophoria, but if the higher image should be found at the left of the lower, heteronymous deviation indicating exophoria is shown. In order to measure these deviations with accuracy the prism must be held with its base precisely downward, but we may estimate a deviation by turning the prism a certain number of degrees from the primary position, the strength of the prism and the amount of the turning being known (Graefe).

This test with the vertical prism having been made at the distance of twenty feet, the power of abduction is then to be determined. As stated in the previous paper, the standard of normal abduction should be about 8° . But the fail-

ure to overcome a prism of 8° with its base inward at a distance of twenty feet does not prove that the visual lines actually tend inward, nor does the ability to overcome prisms of higher grades show that these lines tend outward. This restriction of abduction power on the one hand, or its excess on the other, while under ordinary circumstances indicating a tendency inward or outward of the visual axes, in a certain proportion of cases may be the manifestation of some complicating tendency. Hyperphoria, for instance, not unfrequently gives rise to irregular abducting energy. In a case in which hyperphoria of 1° or 2° may be found, esophoria of several degrees may be shown by the test of the vertical prism, while the abducting power may reach 12° or more. On the other hand, the vertical prism may show 2° or 3° of exophoria while the abducting power may be restricted to 4° or 5° which cannot be increased by any adjustment of the prisms to favor the hyperphoria. An operation for hyperphoria will, often but not always, bring these conflicting evidences into harmony. Not every case, however, appears to be thus explained. In a certain number of instances we find restricted abduction with exophoria, or excessive abduction with esophoria, and no other complicating tendency appears to manifest itself even after patient search continued through some months. In general, esophoria is attended with restricted abduction, and as a rule we may accept the fact of inability to overcome a prism of 8° with its base in as indicating an inward tendency of the eyes, unless exophoria is positively shown by the vertical prism.

The test for esophoria having been made at the distance of twenty feet, it should be repeated at the near point. A convenient form of test object is a small cross. The vertical arm of the cross serves to give an idea of the relative position of the images, but does not, like Graefe's dot-and-line test, conceal the deviating tendency by the effort to fuse the double parallel lines. If at the near point the images still deviate homonymously, we have esophoria in accommodation. It not unfrequently occurs that esophoria is shown when the test is made for the distant point, and that exo-

phoria appears by the test in accommodation. Here, as in the case of inconsistencies between the esophoria and abduction tests, hyperphoria is to be suspected. It is likely in this latter case that the influence of the superior muscle in causing the upward tending of one eye gives rise to a swinging movement, which is shown as exophoria in accommodation. I have elsewhere¹ discussed at some length the theory which has been rather generally held, that in these cases "insufficiency" of one set of muscles exists for one distance, and "insufficiency" of the antagonizing set is the condition for another distance. It is to be admitted that all muscles may be weak. It may therefore be admitted that both the external and internal recti may be weak. Are we therefore to assume in every instance, or in any considerable proportion of instances, in which opposite results were found by tests at different points, that when one looks at an object situated at twenty feet there is "insufficiency of the externi," in the sense of too little power to antagonize the interni, while at the near point there is "insufficiency of the interni," in the sense of inability to antagonize the externi? We may find assistance in answering this question, in many instances, by ascertaining the relative power of the opposing muscles in abduction and adduction. Let us take an example which fairly represents a very large class of cases.

Let us suppose that, in our example, a not uncommon one, by the vertical prism we find esophoria 4° , and in accommodation exophoria of 7° or 8° . By abduction the patient overcomes a prism of 8° or even 9° . This abducting force is equal to the ordinary standard, and therefore indicates no weakness of the externi. They can overcome the tension of the interni from the position of equilibrium to an extent as great, or even greater, than the average muscles of their class.

On the other hand there is a power of adduction of 50° . This indicates equally that there is no "weakness" of the interni or failure of power to act when the question is one between these and their immediate opponents. It is true

¹ Transactions International Medical Congress, Washington, 1887.

that there may be a good abducting power coincident with a tendency of the visual lines inward, and the proposition holds good respecting the opposite conditions; but, taken together, the theory that both these opposing sets of muscles are alternately "insufficient" for the other is wholly illogical. We have in our case adequate power of abduction, showing that there is no essential "weakness" of the externi, and full adducting power, proving that the interni are supplied with ordinary strength. With esophoria at distance and in accommodation we might readily and logically conclude that, with full power of each of these opposing sets of muscles, a relative inequality of length of the muscles, or an imperfection of adjustment, would account for the inward tendency; and the same might be said of exophoria at the far and near points under similar circumstances. I hold it absolutely illogical, in view of such facts, to retain the idea of "insufficiency" of both sets of muscles in such cases as that used in the illustration. We must seek for a more reasonable explanation. This, as already stated, I have found in a very considerable proportion of cases in the fact of the existence of hyperphoria. As in the class of cases already cited, in which hyperphoria gives rise to irregularities in the abducting or adducting power, so it is often, if not usually, the complicating element in these contradictory cases in which esophoria is found at one point and exophoria at another. It is not always easy to discover the hyperphoria in these cases. It may elude discovery during several examinations, but the presence of the contradictions under discussion should, I believe, always suggest the existence of hyperphoria. Not until that or some equally important element of disturbance is found should we rest in the belief that we have discovered the actual tendency of the visual lines.

These contradictory conditions include a very large class of cases, and, unless studied from a proper standpoint, a class of cases presenting very great difficulties, both as to diagnosis and treatment.

In a certain number of cases I have been able, after long-continued search, with failure to discover the real muscular

balance, to find the faulty tendencies, after faithfully excluding one of the eyes during some days or weeks. In order to be effectual, the exclusion must be nearly perfect, and the patient must not indulge in the occasional use of both eyes.

The results of this method are to be accepted with great caution, rather as suggestive than conclusive.

It is well known that it is not unusual that one eye, the vision of which is lost by disease or injury, will turn outward. This happens in so large a proportion of cases that it cannot be supposed to be in most instances the result of any original balance of the eyes outward. In like manner, after excluding an eye for one or two weeks, we may find a marked condition of exophoria, which will correct itself after a return to the use of both eyes. Notwithstanding the uncertainty of value of results obtained by the exclusion of one eye, it is a method which in a small proportion of cases has led to information which I have not been able to obtain otherwise.

If we inquire concerning the position which the condition esophoria has occupied in the literature of ophthalmology, we shall find that it has received far less attention than that to which its importance has entitled it. There has existed in the profession a vague and possibly not very fortunate tradition that "insufficiency of the interni" constitutes, excluding strabismus, the important anomaly of the ocular muscles; and this condition has been elevated to an unmerited prominence at the expense of other muscular defects equally if not more deserving of attention than itself. The school of Graefe has, for more than twenty years, dominated in this field of inquiry, and Graefe looked upon the task of adjusting the eyes in the act of reading or working with the hands, as holding a pre-eminent importance. It is no disrespect to the great name of Graefe to assume that this view was and is much too limited. It is not disparaging the consummate abilities or the value of the teachings of this leader in thought to believe that, when all these muscular anomalies have been more fully considered, the condition which principally occupied Graefe's attention in this connec-

tion will be looked upon as that holding the lowest rank of the group in importance.

In Graefe's extensive treatise on muscular asthenopia, his most important reference to "insufficiency of the externi" is included in the following brief paragraph:

"There is another cure for asthenopia based on the storing of the relative range of accommodation. If we weaken by a tenotomy of the internus, the power of action of the latter in a proper manner, so that the proper convergence of the eye in question continues (and this result may be easily reached by tenotomy with the conjunctival suture), then a given degree of convergence is accompanied by a higher degree of accommodation than before. And corresponding with this will be an approach of the relative accommodation to the near point.

"The demand on the energy of accommodation then becomes less. We have produced an effect nearly equal to that which we produce by placing a prism with its edge in, producing voluntary squinting, or as though the patient had squinted for his own relief.

"It is essential to consider, however, in this connection, that by enfeebling the interni beyond a certain measure (even through the use of an adducting prism) we induce slight muscular asthenopia."¹

Graefe says he has resorted to this expedient only twice, and then only in cases where experiments made with prisms (colossal prisms) showed that they were overcome by adduction, giving him the surety that no troublesome insufficiency would result, and where, besides, a very evident movement of the relative range of accommodation had been shown beforehand.

Graefe adds: "In any case the method remains more interesting than practical in comparison with the more peaceful choice of spectacles."

Even here it will be seen that the aim was to secure an approach of the relative range of accommodation to the *absolute near point*; in other words to obviate difficulties arising at the reading distance. It is impossible to form a

¹ *Arch. f. Ophthalm.*, viii., 2, 321.

judgment of the precise condition which was found in these two cases, or the exact result of the operative measure; but it appears certain that Graefe found little encouragement in this method of treatment, since he came to regard it as interesting rather from a theoretical than from a practical point of view.

There is in this little reference to the preponderance of the interni, no solicitude for the equilibrium of the long muscles when the eyes are directed to a distant object, nor for any absolute adjustment of the visual lines at various points; the burden of this paragraph is that with certain efforts at accommodation, especially in hypermetropia, there may occur a slight convergent squint, which influences the relative range of accommodation. This, he says, may be relieved by tenotomy, not graduated to secure equilibrium at the point of least enervation, but enough in the judgment of the operator to prevent insufficiency of the interni at the same time making a higher degree of accommodation necessary than before.

This view cannot in any respect be classed with the view of esophoria which has been advanced in the preceding paper or in this. It is an expedient for the relief of or rather for the exercise of the accommodation, not a remedy for esophoria.

To illustrate the disregard of Graefe for any "insufficiency of the externi," less than positive strabismus, I shall quote at some length, from his great article on asthenopia, his remarks upon the graduation of the extent of the tenotomy in operations for "insufficiency of the interni."¹

"As point of departure (for the graduation of the tenotomy) we must choose according to the *reading distance* of the subject. . . .

"If we should even do a little too much, it would not at the near point cause the least trouble. Strabismus convergens could only occur *if we have exceeded the measure of the total abduction* of which the insufficiency constitutes by far the smaller part. This would be a great mistake. Should we keep within this measure (in over-correction of the insuf-

¹ *Loc. cit.*, p. 349.

ficiency) then the correction would for the near point be reached the more easily, and at most the disadvantage would be the too great reduction of the relative range of accommodation." In discussing further the results of over correction he says :

" There will then become necessary at the distance a tension of the externi. This in itself is, fortunately for the tenotomy, of no consequence ; as, for the act of vision at the distance the same results from continuous strain do not occur. Against this however occurs a real trouble. If in the main, the power of the externi is no longer sufficient for fixation at the distance, strabismus convergens with homonymous diplopia is the result. When, in brief, will this occur? Necessarily if the definite effect of the tenotomy does not correspond to the extremest abduction for the distance. We therefore find the measure for the tenotomy by ascertaining the strongest prism which can be overcome by divergence for the distance. The linear deflection which corresponds to this prism, we can remove without harm in order to take from the interni, at the near, as much work as possible. After such an adjusted tenotomy, binocular fixation for the distance takes place, of course, with the *greatest strain* for the externi. What is then required of the externi for the distance favors the interni at the near point. If we had taken only the insufficiency for the distance and not the total abduction, then we would have unnecessarily sacrificed to an illusory advantage for the distance (tension of equilibrium) a part of the real advantage for the near."

Respecting the above, Graefe says : " I have here spoken of the permanent effect. The temporary one may be even considerably greater. We may exceed without harm the abduction for the distance by from two thirds to three fourths of a line, so that there will result, in the median line for the distance, homonymous double images which are united by a minimum prism of 10° ."

Graefe adds that he has often operated to such an extent that prisms of from 15° to 20° were required, not to correct the insufficiency of the externi produced, but to unite the

double images resulting from the temporary converging strabismus. In his illustration of the different grades of the affection and their treatment he says: "Let a second patient have at the near point insufficiency (prism) 16° , at the distance insufficiency (prism) 6° with abduction (prism) 16° . We can take from him by tenotomy the full insufficiency for the near, as that is equal to the abduction at the distance; thus he will now be just able to fix for the distance, *though with greatest possible strain of his abducting power, to which, as we have already found, there is no objection.*" Even when the abducting power is no more than 4° Graefe still recommends weakening of the externi to the point of complete abolition of the abducting power.

It will thus be seen that any insufficiency of the externi short of actual converging strabismus was regarded by Graefe as a matter of no consequence, provided he could secure less of tension at the reading distance.

Indeed, herein is found a radical difference between the system taught by Graefe and that which has been pointed out in these papers, as well as in my former writings. Graefe sought to adjust the eyes for the near point at any sacrifice of the relations of the visual lines at greater distances short of absolute diplopia. His examinations at a distance were not in the interest of actual equilibrium of the ocular muscles, but in respect mainly to the question of how much could be sacrificed in the effort to establish binocular vision at the reading point. In the system here presented, perfect equilibrium, in all respects, in vertical as well as lateral directions, and at the point of greatest relaxation both of the directing and accommodating muscles, is the end to be attained, in the expectation that, this being established, easy adjustments will result at all points, near and distant.

The great majority of text-books completely ignore non-strabismic insufficiencies of the externi, muscular asthenopia and insufficiency of the interni being synonymous terms. Thus Soelberg Wells¹ devotes a section to the discussion of "Muscular Asthenopia (Insufficiency of the Interni)."

¹ "Diseases of the Eye."

His tests for the affection are all made at the near point, the principal one being the dot and line of Graefe. In determining abduction and adduction he removes the object to a distance of from six to ten feet.

Galezowski¹ discusses "Latent Divergent Strabismus, or Muscular Asthenopia," and says that muscular asthenopia is due to "insufficient contractile force of the internal recti." His only test is the dot and line, and made at a distance of fifteen centimetres from the eyes. The third edition of this work, very recently issued (1888), advances no change of view.

Landolt² defines muscular asthenopia as "insufficiency of the internal recti muscles." In his later writings³ he lays much stress upon insufficiency of the converging force, but does not consider the effect of insufficient diverging power or of insufficiency of the externi.

Stelwag⁴ says: "The immediate cause (of asthenopia) is *always* the overburdening of the muscle of accommodation, or of the *internal recti*, as the case may be." In a single sentence in one edition there appears a recognition of "insufficiency of the externi" as a possible cause of asthenopia.

Schweigger, in his work on "Squint,"⁵ devotes a chapter to "Muscular Asthenopia," which he attributes solely to insufficiency of the interni.

Without further reference it may be said that these representative works fairly indicate the importance attached to the condition we are now discussing, and that they indicate that no significance was attached to the condition, except in a single instance, where a brief reference agrees with Graefe's view that an insufficiency at the point of strabismus might become an element of disturbance of relative accommodation. Even this limited and wholly inadequate

¹ "Maladies des Yeux" (first edition), pp. 739 and 789.

² "Manual of Examinations of the Eyes"; translated by Burnett.

³ "L'Amplitude de Convergence," 1885; "Insufficiency of the Power of Convergence," 1886; "Refraction and Accommodation of the Eye," 1886.

⁴ "Diseases of the Eyes."

⁵ London translation, 1887.

view was, by almost universal consent, relegated to the realm of the impractical.

I have seen nothing in the literature of ophthalmology, until attention had been called to the subject in my own writings, which, in any degree, controverts this opinion of Graefe. It is true that there occur, in great rarity, references to the condition of insufficiency of the externi; but, as the cases which have been cited as illustrations are only moderate cases of strabismus, such as under the definition of esophoria given above would be excluded, it can scarcely be said that the subject has received any attention at all. Cases in which diplopia is manifested at the distance of twenty feet, upon the introduction of a colored glass before one of the eyes, even should that diplopia not exceed 2° or 3° can hardly, by any process of logic, be regarded as included within the limits of esophoria. And the fact of the presence of diplopia, even in smallest degree, is a fact presumptive of habitual failure to unite images, for, during an examination, with the attention of the patient closely fixed upon the object, he is likely to make his best efforts, and if he fails in this, it is highly probable that he does not succeed under ordinary circumstances.

In a paper on *Oculo-neural reflex irritation* read at the International Medical Congress at London, August, 1881, a case was reported in which tenotomy of one of the internal recti muscles had been made in which an insufficiency of the externi of only 2° at twenty feet existed. The patient immediately after the operation had no insufficiency, and was able to overcome a prism of 10° by adduction. The patient had been an epileptic, and an entire relief from epileptic seizures had followed the operation. I may add that relief continues to the present time. At the same Congress in another paper, a similar operation for a similar condition was reported, in which the most marked relief had followed in a case of nervous disease. In an essay presented to the Royal Academy of Medicine of Belgium, December, 1883, I reported having at that time performed operations for this defect in three hundred and fifteen cases, and many of those cases were given in detail. Up to the present time I have

performed this operation for the relief of esophoria in more than two thousand cases.

In respect to the clinical importance of esophoria, which occurs in the proportion of more than three to one of exophoria, it plays a much more important role than the latter as a predisposing cause to a variety of neuroses; and, as the immediate cause of asthenopia and kindred affections about the eyes, it is an element of great disturbance. It is probably true that in an individual case of exophoria, the strain in adjusting the eyes may be more immediately expressed in the orbit in the form of localized pain of the over-strained muscles than in an average case of esophoria of equal extent. The reactions of esophoria are likely to be more distant. Thus, the patient affected with exophoria may, after an hour spent in reading, suffer from pain in and immediately about the orbit. On the other hand, the patient affected with esophoria, after attending church or the opera, or after visiting a picture gallery, where the eyes have been directed during a considerable time at a distant point, and in such position as to hold the visual lines in parallelism, the result is quite likely to be a universal malaise, with pain at the back of the head and in the upper part of the neck, and possibly, if the patient is not strong, a sense of illness all the following day.

Reviewing a large experience in comparing these two conditions, I find that the general or distant reactions from esophoria are far more frequent and significant than those of exophoria, and that the local pains, while possibly absent in a greater proportion of cases, are still of great prevalence and of a more persistent character when existing.

The grade of the deviating tendency does not always mark the extent of irritation resulting from it. Indeed, these anomalies of the ocular muscles sometimes result in less serious reactions when extreme than when moderate. Thus, in a case of esophoria or exophoria of 2° or 3° the defect is sometimes a source of greater irritation than one on the verge of strabismus, of 8° or 9° ; because in the first instance binocular vision is constant, or nearly so, although effected by strenuous effort. In the second case the image

of one eye is often suppressed, and the eye is permitted to drift away from the physiological companionship of its fellow ; thus affording a rest of one kind at the expense of another sort of nervous perplexity. This principle is sometimes illustrated after operations in cases of complicated strabismus. If a patient who has, for instance, a widely divergent strabismus with moderate deviation of one eye above the other, is subjected to an operation for the correction of the divergence, the patient at once becomes annoyingly conscious of double vision, and this consciousness remains until the correction of the vertical deviation is made. Of course such a patient had never been free from double vision previous to the first operation, but the consciousness and annoyance only arose when the double images were brought into very close proximity.

It is not an uncommon circumstance that, of two members of the same family having similar tendencies of heterophoria, the member manifesting the lesser defect is often the one to experience the most serious nervous reactions. It does not follow that the latter of the two mentioned has actually less anomalous tendency than the other, but such a one by a more strenuous effort may conceal what the other reveals, and by this very effort induce the nervous disturbance.

It is not to be supposed that because esophoria is more often than exophoria the predisposing cause of distant disturbances, it is therefore not a notable cause of asthenopia. Of a large class of cases which go from one oculist to another in the hope of relief from some new treatment and submit to an almost endless change of spectacles with little if any advantage, a very considerable number are victims of very slight grades of esophoria. They gain no relief until this too much neglected anomaly receives due attention, when their asthenopic symptoms disappear.

To the ordinary phenomena of asthenopia may be added the following symptoms which are prominent among the local indications of esophoria.

In a certain proportion of cases, especially those in which esophoria approaches the extreme limits to which binocular

vision can be maintained, the accommodation is suppressed in order to avoid too excessive convergence at the near point; the patient preferring an imperfect accommodation, and hence an indistinct image, to a more perfect accommodation with loss of perfect union of the images of the two eyes. The habitual suppression results in weakened power of accommodation, which is often associated with a widely dilated pupil. Even after an entirely successful operation for the relief of the esophoria, the accommodation sometimes remains enfeebled and the pupil sluggish and expanded for many months, continuing the symptoms of asthenopia and headache.

In esophoria, especially when combined with hyperphoria, one of the very unpleasant symptoms not unfrequently met with is the annoyance experienced by the patient in constantly seeing the nose. This may appear a trivial symptom, yet it is described by those subject to it as a most vexatious phenomenon. Many patients declare that they can bear the pain of the head and back resulting from the muscular condition better than they can endure the never ceasing annoyance of seeing the nose.

In similar conditions patients not unfrequently complain of seeing a black spot in the centre of the field of vision. Thus while reading, a black spot is frequently present at or near the part of the page at which the reader is looking, causing annoyance and confusion. This black spot would appear to result from a temporary failure of the visual lines to unite at the desired point, permitting one eye to float inward to an extent that the blind spot appears at the reading point.

The effect of esophoria on vision, while, in the lesser degrees, not so pronounced as that which has been shown to result from slight grades of hyperphoria, is, in moderately high degrees, of a most unequivocal character.

Amblyopia has been shown to be rather the rule than the exception in hyperphoria. In esophoria, amblyopia is the rule when the deviating tendency exceeds 2° . The visual condition of 100 consecutive uncomplicated cases of esophoria was examined with the following result: no case

in which hyperphoria of 1° existed, or in which hypermetropia or myopia exceeded 3.00 D, or in which astigmatism of more than 1.50 D was found, nor any case of disease or injury being admitted to the list.

In these 100 cases the average vision of the 200 eyes (no case being recorded at more than $\frac{20}{20}$) was equal to a small fraction less than $\frac{20}{20}$. It thus appears that in slight grades of esophoria the tendency has little if any influence upon the state of vision.

In 100 other cases in which the degree of esophoria was not less than 3° or more than 8° , the vision is shown in the following table. In these cases, as in the first series, all complicating deviating tendencies were excluded, and the restrictions in regard to disease or injury and in regard to refraction were the same. The table shows the number of best eyes and of worst eyes having certain grades of vision from $\frac{20}{20}$ to $\frac{20}{100}$. In each case one eye is reckoned as best and the other worst, even when both were of similar grade.

TABLE :

| Vision. | Best Eyes. | Worst Eyes. |
|--------------------------------------|------------|-------------|
| $\frac{20}{20}$ | 36 | 28 |
| $\frac{20}{25}$ | 46 | 39 |
| $\frac{20}{30}$ | 15 | 23 |
| $\frac{20}{40}$ | 2 | 4 |
| $\frac{20}{50}$ | 1 | 2 |
| $\frac{20}{60}$ | — | 4 |
| $\frac{20}{100}$ to $\frac{20}{100}$ | — | — |
| | 100 | 100 |

It appears from the above table that the average vision in esophoria of more than 3° is materially reduced, and that :

The average vision of 100 best eyes is about $\frac{20}{27}$.

The average vision of 100 worst eyes is about $\frac{30}{50}$ or $\frac{20}{35}$. In other words, the average loss of visual power of the 100 best eyes is nearly $\frac{1}{3}$, while the average loss of the 100 worst eyes is nearly $\frac{1}{2}$.

It is only reasonable to suppose that a condition which must of necessity act as a constant cause of nervous perplexity and irritation, should result in inducing a state of hyperæmia or of altered nutrition of the parts supplied

to a certain extent by branches of the same nerves which supply the imperfectly balanced muscles. It could scarcely happen that an irritative cause so prolonged in its existence and so efficient in inducing functional disturbances should fail to be a frequent cause of such perverted nervous influences upon the eyes themselves or their immediate surroundings as to promote pathological changes of divers forms. Hence, for instance, it is not a surprising fact that one who, during a lifetime, has contended with the irritating influences of heterophoria, should at length find that the nutrition of the crystalline lens has suffered degenerative changes, or that even the tunics of the eye should be affected unfavorably. This view of the possible or probable origin of many affections of the eye is not one to be regarded with disdain or treated as the outgrowth of extreme views. Diseases do not usually occur spontaneously. They are the result of laws, and it is idle for us to speak of cataract or corneal ulcer or of various other affections simply as accidental or providential visitations; and a fallacy to talk about "constitutional causes," when we mean that we do not know. A known cause which may induce perverted nervous action is of more practical consequence than a volume of profound ambiguity. Many years ago I called attention to the influence of refractive anomalies as predisposing causes of corneal ulcers,¹ and I have since had the satisfaction of observing that several close observers have arrived at similar conclusions. I cannot doubt that refractive and muscular lesions are very largely effective in the causation of various eye affections both internal and external.

True there are certain well-known general physical contaminations which are manifested as local affections; but even in the presence of these sources of unmitigated evil we may learn that the localizing of the virulence is favored by a damaged or enfeebled state of the nerves supplying the affected part.

Hence in many chronic and obdurate affections of the eye we may look upon the conditions of anomalies of refraction and of the eye muscles as probable sources of mischief.

¹ Transactions International Congress, Philadelphia, 1876.

Should a case of incipient idiopathic cataract present itself, and should I find associated with it pronounced anomalies of the eye muscles, I would most surely advocate the rational treatment for these conditions. Would the cataract stop? Perhaps not. But in many cases within my experience it has stopped. It would be doing a rational and intelligent act to relieve the patient from a source of irritation which might affect the nutrition of the lens unfavorably. The arrest of the complaint might not follow, but the surgeon has made no mistake if he performs his work well, and he has a reasonable expectation that the pathological process may be arrested.

The distant effects of esophoria include a vast number of disturbances, localized or more general. It is unnecessary to speak of these in detail. Prominent among them are vertigo, nausea, insomnia, headache, and backache. Many of these distant effects are discussed at length in my work on "*Functional Nervous Diseases*."

A large class of people who from year to year are supposed to suffer from "malaria," "biliousness," "nervous prostration," "dyspepsia," and similar neurasthenic conditions are simply paying the penalty of uncorrected esophoria. The effect of this and other forms of heterophoria are frequently seen in their influence upon the physical functions. Chronic constipation, disurea, and dysmenorrhœa are not infrequent results of the reflex irritation from heterophoria.

Treatment of Esophoria.

While recognizing esophoria as an important anomaly, there may reasonably be a diversity of view respecting the manner in which it is to be treated and the extent to which treatment should be carried.

In the first place it may be held that in case of asthenopia or of more general nervous disturbance from esophoria, treatment directed to the improvement of the general tone of the patient by means, of tonics, rest or change, by the local stimulation by electricity, or other familiar means, the nervous manifestations may disappear. To a certain extent this may be true; but what then disappears is not the disadvantageous condition but the temporary results.

The defect remains to renew its unfavorable influence whenever, as the result of a lowering of nervous vigor through prolonged fatigue or anxiety, or through sudden shock or exposure to unfavorable influences, there remains too little nervous energy to accomplish the ordinary requirements of the individual and to correct the defective muscular tendency. It follows that the relief by the methods named can only be temporary and is by no means radical.

But it may also be questioned whether esophoria of slight degree should be subject to treatment.

I have already pointed out the fact that the reactions from these muscular anomalies are not in proportion to their extent. A condition of esophoria of 1° or 2° may induce a train of nervous symptoms of great importance, and which in spite of any treatment short of relief to the defect itself may continue during many years. I am convinced that any deviating tendency in this direction is a physical disadvantage and should be removed.

But is it proper to interfere with such a condition on purely theoretical grounds, although the subject of the defect may not experience any conscious discomfort from it? At present it is a question to be settled by the individual judgment of those most interested. We should, however, bear in mind the fact that esophoria is a condition which demands constant correction by the person subject to it. This correction demands an expenditure of nervous energy which would not, in the absence of esophoria, other things being equal, be required. In other words, esophoria causes a waste of nervous power. When we recall the continuous nature of this waste and the amount of force at times required to regulate the action of the eye muscles, it will hardly appear extravagant if we assume that even should the subject of esophoria, by virtue of an abundant supply of nervous energy or as the result of favoring circumstances, suffer no conscious annoyance, he is nevertheless deprived of a certain amount of nervous ability which he might otherwise possess, and however capable such a one may be, his powers are still less efficacious than they might be in the absence of an enervating cause. This is a practical fact already demonstrated in an abundant number of cases.

By only two methods can we hope to relieve the tension and perplexity of esophoria. They are by the use of prisms and by tenotomy. I have elsewhere expressed my views respecting the value of prisms in the treatment of heterophoria. They are invaluable as aids in determining the condition of the ocular muscles, not only to be used in the consulting room, but to be worn temporarily by the patient. It is my custom to keep on hand a large number of spectacle frames of uniform size, and a quantity of plain prism glasses of 1° , 2° , and 3° , which can be, without loss of time, slipped into the frames. With these I am able in a moment to arrange temporary prisms for a patient, who may be required to wear them for a few days or a few weeks as the case may be, and such changes in strength of prism can be readily made as circumstances may require. In this way latent heterophoria may become manifest. When no longer needed the glasses are returned and may be used for another. After all that can be done by the wearing of prisms and by gymnastic training by prisms in the hands of the surgeon, there remains *the most effectual and satisfactory treatment, graduated tenotomy.*

It is a matter of the greatest importance to determine precisely under what conditions tenotomy is permissible or advisable and to what extent it may be carried.

For the purpose of greater clearness I will divide the cases into two classes:

1. Simple cases in which the indications are not contradictory.
2. Complicated cases in which the evidences are inconsistent, or in which evidences in the same direction are manifestly disproportionate.

Of the first class we may meet with a variety of conditions.

a. There may by the vertical prism be found no manifest esophoria, nor is hyperphoria shown by the horizontal prism, but *the abduction power is less than the standard.* If, after training the abducting muscles by requiring them to overcome gradually increasing prisms a few minutes at a time for several days, the abducting power remains too low,

a weak prism may be worn for a few days with its base out. If even then there is no manifest esophoria and the abducting power is the same or less, and if there is no exophoria in accommodation, an operation is undoubtedly permissible.

b. Less difficult is it to decide if with the restrictions of abduction there is manifest esophoria, provided that the limitation of abduction and the degree of esophoria are proportioned. Should the restriction of abduction be only 1° or 2° while the manifest esophoria should amount to a considerable greater number of degrees, there would remain a doubt whether a complication does not exist, and operation would only be warranted after repeated investigations.

The second class may present far greater difficulties. Here we may have :

a. Restricted abduction with exophoria as shown by the vertical prism.

b. Restricted abduction with or without exophoria but with exophoria in accommodation.

c. Full or excessive power of abduction with esophoria.

All these conditions are liable to be the result of a complicating tension, most frequently of hyperphoria, and whether manifest or latent great caution should be observed before operating, to determine the presence and nature of the complicating element. Should hyperphoria be found, it should always receive attention first.

After the correction of hyperphoria the case may be greatly simplified.

Should hyperphoria be found in a case in which the indications of esophoria are uniform, we should first correct the hyperphoria unless esophoria is of so pronounced a degree as to render it possible that the hyperphoric tendency is a result of the tension of lateral muscles. In such cases an operation for the partial correction of esophoria may be first made.

Very marked and salutary results often follow a tenotomy in case of esophoria of 1° or 2° or in case of abduction of only 5° or 6° . For cases illustrating this the reader is referred to some of my previous works.¹

¹ See especially "Functional Nervous Diseases," D. Appleton & Co., 1887.

The method of operating in heterophoria has been described in the former paper.¹ Since writing that paper the method has been still further modified, and I shall here only refer to the modified steps in the operation.

In making the incision through the conjunctiva the smallest possible opening is made, precisely over the centre of the insertion of the tendon. The opening should be less than $\frac{1}{2}$ millimetre in extent. Then the blades of the scissors are introduced with greatest care one on the scleral and the other on the conjunctival side of the tendon, when they are insinuated toward the border, then pressed strongly against the insertion of the tendon.

In order to permit the blades to be introduced in this small wound and to be carried properly into position for cutting the tendon, they have been modified in an important manner. As now made the blades are quite thick and



Subconjunctival Tenotomy Scissors.

strong until within about one third of an inch from the extremity, when they become suddenly very slender, the two united being less than the size of No. 1 Bowman's probe. The points, although so extremely delicate, are perfectly strong and "walk and talk" together in the most perfect manner. There is no catching or failure to cut under any circumstances.

In operating for esophoria a certain allowance is to be made for the contraction which occurs in the process of healing.

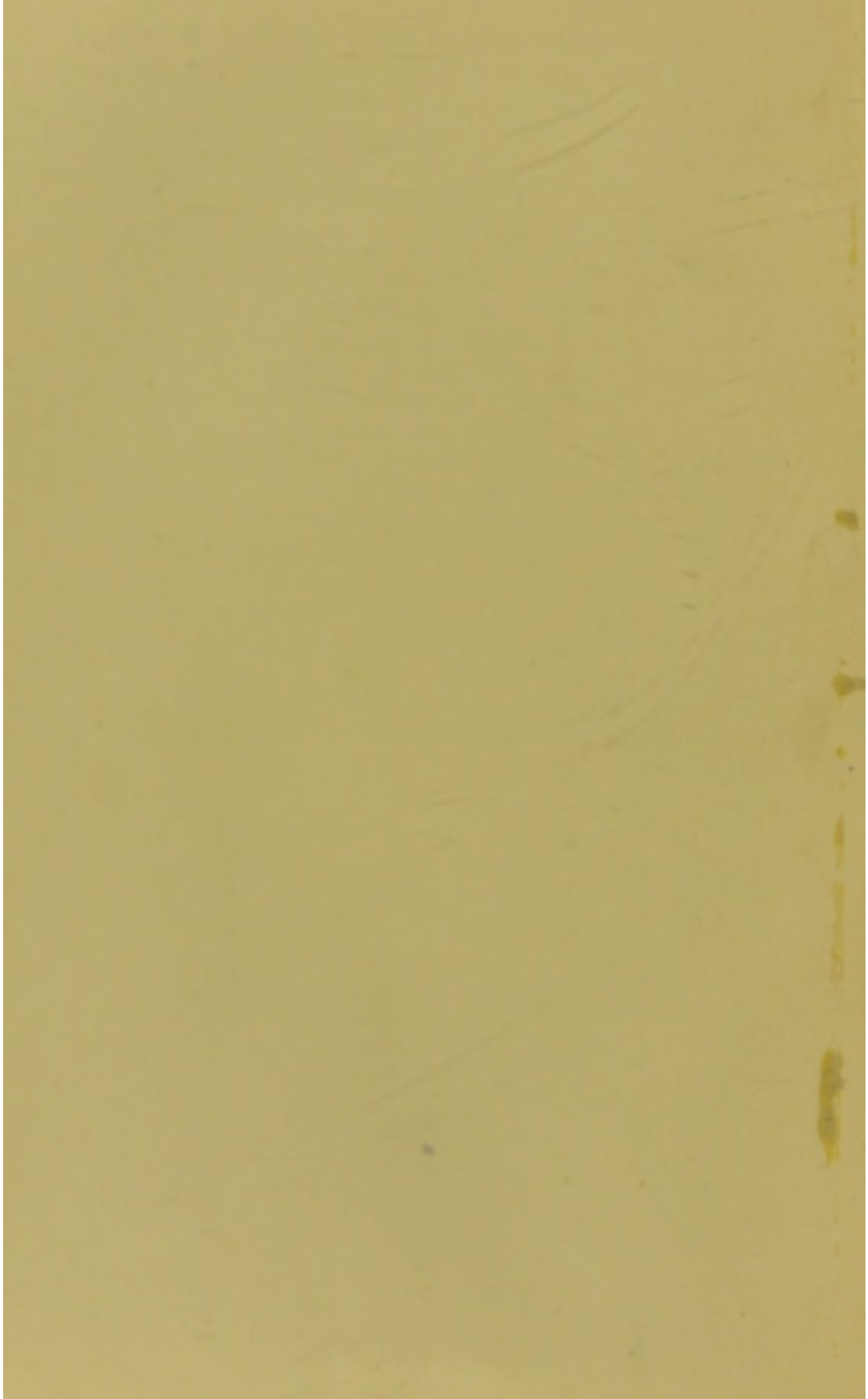
I have found it advisable to allow not more than 1° or 2° exophoria immediately after the operation, with abduction of 11° or at most of 12° . If we allow a greater degree of exophoria or of abduction, we are open to risk of permanent exophoria. Exophoria of 1° or 2° on the day following the operation is liable to progressive increase, and should

¹ ARCHIVES OF OPHTHALMOLOGY, June, 1887.

the abduction remain in excess with exophoria 1° or more on the next day after the operation, the excess should be corrected. An exophoria 1° or 2° , with abduction of 11° or 12° at the time of operation, very rarely, if ever, shows an over-correction after the the first few hours. On the following day after such an operation, we should hope for abduction of 8° with no esophoria.

Should it be required to reduce the extent of the operation, it can be accomplished in the following manner: A delicate Tyrell's hook is introduced beneath the conjunctiva and the divided extremity of the tendon. The hook is then turned with its point forward and pressed against the central part of the tendon when traction is made. The extreme cut border of the tendon is drawn into the small opening of the conjunctiva when a needle carrying a No. 000000 silk thread is passed as near to the edge as possible. It is then passed into the sub-conjunctival tissue at the corneal side of the wound and outward, including the conjunctiva to the extent of less than one millimetre. The thread is tied so as to graduate the tension, bringing the tendon forward sufficiently to guard against exophoria while preserving the required relaxation.

This procedure, when required, should be made with the finest of thread and with the most extreme delicacy of manipulation.



ANOMALIES OF THE OCULAR MUSCLES.

THIRD PAPER.

BY DR. GEORGE T. STEVENS, NEW YORK.

With four wood-cuts.

V.—EXOPHORIA.¹

THE term Exophoria signifies “a tendency of the visual lines outward.” The condition is supposed to be ascertained when all the muscular tensions are at their minimum, especially when the exertions made necessary in accommodation are, as absolutely as possible, absent.

In order to arrive at a knowledge of the condition, the test object must be so far removed from the eye that a full relaxation may be obtained. Such a relaxation demands, not that the test object should be at an infinite distance when the distance between the eyeballs is considered, for practically a distance of not less than twenty feet will serve to place all the ocular muscles in a condition of essentially minimum innervation, and will make due allowance for what is known as the “muscular mesoropter.” At this distance, then, if we induce diplopia by means of a prism placed exactly vertically before one eye, or by prisms vertically placed before each eye, the base of one exactly up, of the other exactly down, the deviation heteronymously of the images of an object in the same horizontal plane with the eye, is the indication of exophoria. The phorometer affords us the most satisfactory aid in making such an examination, for it not only avoids the inaccuracies almost unavoidable in

¹ Gr. *φωρά*, a tending.

extemporary methods, but aids materially by revealing with ease any coexisting and complicating anomalous tendencies. The number of degrees of prism required to correct the heteronymous deviation, as shown by the vertical prism, marks the extent of exophoria.

A second condition, and one nearly always associated with exophoria, but very often found in its absence, is *exophoria in accommodation*.

By exophoria in accommodation we understand the condition answering to the same general tests as exophoria, but with the test object at the ordinary distance of reading, or about $\frac{1}{2}$ metre. It must not be understood that exophoria and exophoria in accommodation are one and the same condition, shown in greater or less degree according to the distance at which the tests are made. The two conditions may be the expressions of entirely different influences. In all our study of these anomalies this radical difference should be kept in mind.

Another important fact should not be forgotten, namely, that while in theory the position of the images of the two eyes when separated by prisms indicates the tendency of the optic axes, the fact remains that the influence of the prism in demanding an attempt at correction of the diplopia may become also an element of disturbance in the lateral relations of these axes. The method of determining the mutual relations of the optic axes by means of prisms has certain disadvantages which should be recognized in all such examinations. Unfortunately no other method at present known can take the place of the use of prisms. That exophoria in accommodation is, in a certain proportion of cases, a result of the interposition of the vertical prism, appears exceedingly probable. That the prism if not too strong is rarely the cause of exophoria, appears also fairly certain.

Our interpretation of the deviating tendencies, whether at distance or in accommodation, must depend on a consideration of all the various tests at these different distances. Thus, if exophoria appears when the test is made at the distance of twenty feet, we are to take into consideration

also the question of hyperphoria, of exophoria or esophoria in accommodation, and of the power of abduction and adduction. Only when all these are made elements of the problem can any satisfactory decision be reached.

Should exophoria be found both at the far point and in accommodation, should the abduction be in excess, and should no important degree of hyperphoria exist, we may, undoubtedly, interpret these various tests as indicating that the balancing of the eyes is such that the natural tendency of the visual lines is to diverge, and that only an amount of tension on the part of the adducting muscles greater than that required in orthophoria can hold these lines in parallel or in converging relations.

Exophoria is generally the expression of such an actual tendency to diverge. There is, however, a percentage of exceptions to this principle, a percentage large enough to keep us strictly on guard against error.

That exophoria is not infrequently the expression of hyperphoria is a fact that cannot escape the notice of the careful observer. Indeed certain cases in which hyperphoria exists are at one time high grades of esophoria, and at a somewhat later date are found to be exophoria in as high degree, indicating that the conditions of esophoria and exophoria are accidental, doubtless resulting from the existence of hyperphoria. Illustrations of this interesting fact will be adduced as we proceed.

Now, it only remains to emphasize the statement that exophoria, complicated with hyperphoria, is not unfrequently the result of the latter anomaly.

If this is true of exophoria, it is in a far greater proportion of instances true of exophoria in accommodation. Indeed it is safe to say that by far the greatest number of cases in which exophoria in accommodation occurs, its presence does not indicate any actual preponderance of energy on the part of the externi, nor any insufficiency of the interni. Exophoria in accommodation is rarely absent in hyperphoria, although the opposite condition of esophoria in accommodation is, in rare instances, found associated with that anomaly. Not only is exophoria in accommodation char-

acteristic of hyperphoria, it is quite frequently found in simple esophoria. In the case of hyperphoria the existence of exophoria in accommodation is probably explained by the effort at adjustment by the muscles moving the globe of the eye in the vertical direction. It is less easy perhaps to account for the presence of the condition in question in cases of simple esophoria. It is quite possible that the habitual tension of the externi in the act of preventing the confusion which might result from esophoria comes into action, when the prism is used to separate the images of the two eyes, in such a manner as not to permit a convergence of the visual lines exactly proportional to the angle required for the given near point. In other words, it is an instinctive resistance which, under the circumstances of the interposition of the prism, can not be exactly graduated by the muscles engaged. It is also quite possible that by the very fact of the interposition of the prism, the normal adjustments being interfered with, exophoria results. Whatever explanation we may accept for the presence of exophoria in accommodation in simple esophoria with restricted abduction, the important fact remains that we not infrequently encounter it.

Exophoria and Insufficiency of the Interni.

We are now in position to compare the condition of exophoria with the condition described by von Graefe and so well known in the text-books as "Insufficiency of the interni." According to von Graefe, "the affection consists in the insufficient power of the interni, as opposed to the resistances which arise in the binocular act of vision and which manifest themselves in an increased manner at the near point." In fact, notwithstanding a nominal recognition of the relations of the visual lines at distance, the whole line of von Graefe's argument and the entire purport of his procedures of examinations and of treatment, indicate in the most unquestionable manner that practically Insufficiency of the interni related to the reading point. One or two examples from the many which might be adduced will serve to illustrate the correctness of this state-

ment. In speaking of the tenotomy for the relief of insufficiency¹ he finds a difficulty in certain cases in correcting it satisfactorily because a full correction causes homonymous diplopia—in other words, convergent squint, at distance. He is therefore reluctantly forced to leave some of the insufficiency uncorrected. But he is willing to go as far as possible, and he therefore directs that tenotomy be carried to the extreme point of abolishing the power of abduction at distance, although he concedes that this will force the “greatest strain upon the externi” for distance in order to avoid disagreeable diplopia. Indeed he goes much further and says: “If the insufficiency increases rapidly toward the reading distance we can be more liberal (in the tenotomy), and need not fear homonymous diplopia for the distance, to correct which, directly after the operation, prisms of from 12° to 14° are required.”²

Von Graefe even adduces as typical of a class of cases of insufficiency of the interni by no means rare, the following conditions: “Latent converging strabismus, 6° ; abduction at distance, 0° ; insufficiency of the interni, 20° .” The reader who has pursued this series of papers can hardly fail to recognize in this combination the certain indication of a high degree of hyperphoria, an element which von Graefe does not consider in this connection.

Von Graefe’s “Insufficiency,” then, which has received no new interpretation in later works, may be fairly compared to the condition which we have called exophoria in accommodation. It represents, not of necessity, an actual outward balancing of the visual axes (although in point of fact slight degrees of divergent strabismus were included in his class of “Insufficiencies”), but is the manifestation, as we have seen, of various more or less complicating tensions, and may even be one of the expressions of an actual tendency of the optic axes to converge.

That exophoria demands, in the convergence necessary in the act of accommodation, an inordinate tension, and that as the result of such tension pain and fatigue are induced, is evident. Insufficient power of the

¹ *Archiv für Ophthalmol.*, viii., 2, p. 345.

² *Ibid.*, p. 350.

interni is, however, of less frequent occurrence than might be supposed, especially when it is remembered that the condition has so long been known by the term Insufficiency of the interni. In fact the converging power resulting from the increased demands upon the interni is commonly very great indeed. The convergence of the optic axes in a large proportion of cases of exophoria (in which a low degree of diverging strabismus is not included) is for a point as near, and even nearer, than it is found in a very great number of instances where no exophoria exists. Indeed, if we select indiscriminately a considerable number of cases of simple exophoria and an equal number of cases of even moderate hyperphoria, we shall find that the average converging power in the cases of exophoria is considerably greater than in the other. The fact that more than the usual amount of effort is demanded of the interni in exophoria serves to develop the size and strength of these muscles to an extent greater than exists in orthophoria or esophoria. Hence the other fact that the converging point is removed to a greater distance from the eyes than in orthophoria may not, and most frequently does not, indicate a tendency of the visual lines outward when all the muscles are in a state of repose. The ability to converge is often much more considerable in cases where there is actual divergence of the optic axes than in some cases in which there is positive convergence. For instance, in a case now under my observation, behind a screen either eye deviates out one third the diameter of the cornea, and which shows, by the phorometer, exophoria 15° , and exophoria in accommodation of 30° , can fix a small opening through a dark card held toward the light, holding the image of the opening single until it reaches a point $3\frac{1}{2}$ inches in front of the eyes, when one of the eyes can be seen to surrender and move outward. Examples in which, with converging axes, convergence can be made only at a considerably greater distance than this, will be given later. It follows that the phenomenon of insufficient convergence is an unsafe guide to the practical management of any anomalous condition of the muscles. Instead of relying upon this condition,

itself dependent on others, we should ascertain to what the insufficiency of convergence owes its origin. This being found, we may safely proceed to correct the original defects when the insufficiency of convergence will be found to have disappeared.

The following example will serve to illustrate the principle that insufficiency of convergence may be associated with a tendency of the visual lines inward amounting to actual convergent strabismus.

Miss G. W., aged twenty-four. Myopia both eyes (4.50 D and 10. D respectively). Has vertical and converging strabismus. A prism of 6° with its base down before the right eye, and another of 9° with its base out before either eye, unites images but does not correct the whole of the tendency inwards. Without glasses, or with glasses for the correction of the myopia, the nearest converging point is seven inches.

Thus it appears that, even in a case in which there is extreme convergence of the visual lines at a distance, insufficient convergence may exist. But the further study of such a case is instructive. Tenotomy of the superior rectus of the right eye was performed with the result of bringing the images of the two eyes to the same horizontal plane, leaving homonymous diplopia. Tenotomy of each internus was afterward made, resulting in a complete correction not only of the diplopia but of all manifest esophoria. Following these corrections there was found convergence at four inches. Thus, relaxing both interni was followed, not by diminished but by increased power of convergence.

The following is an example of insufficient convergence in a case of simple esophoria :

A gentleman, who had for many years suffered from headache and asthenopia, was found to have hyperopic astigmatism 1. D each eye. Esophoria, 4° (afterward increased, while using correcting prisms of 1° each eye, to 6°). Abduction, 2° ; hyperphoria, 0° ; converging power at seven inches only. Tenotomy has since been made on each internus with the result of correcting esophoria, giving abducting power of 8° and convergence at three inches.

It is evident in this last case either that the interni were weak from disuse or that there was an instinctive resistance to convergence resulting from the habitual guarding against converging strabismus. In both these illustrations it is shown that the relations of the visual lines at the near point can only be accepted as auxiliary to the examination, and that the actual governing tests of muscular balancings must be made at a distance at which all the muscles can be supposed to be in repose.

Physiological Considerations.

Exophoria is an anomaly of the ocular muscles which I have found in much less frequency than esophoria. Indeed, the cases of esophoria exceed those of exophoria in the proportion of more than two to one.

When the relative physiological power of the externi and of the interni is considered, we may well question whether exophoria is often a congenital defect or whether it is not in most cases acquired.

The facts now available do not appear sufficient to warrant any assertion. That exophoria is the congenital condition in a certain proportion of the cases is strongly suggested by the fact that it is so often a family trait, and to all appearances one in which no collateral anomaly is to be discovered which might account for this. Even in cases of well marked and uncomplicated exophoria, the interni retain a considerable preponderance of contractile power.

In practice, the well-known fact that a free tenotomy of an externus produces, compared to a similar operation on an internus, a much less pronounced effect, is an extremely suggestive one in respect to the relative tension of the two opposing sets of lateral muscles.

Still another interesting fact in this connection is that which I have observed very generally in operations upon the externi, that the tendon of the externus is rarely tense, even when the eye is rotated in. In this respect it differs materially from its opponent, the internus.

It is certain that exophoria is not, in all cases in which it exists, an original condition. Just as hyperopia is some-

times observed to pass over to the opposite condition of myopia, so is esophoria sometimes replaced by exophoria. The existence of hyperphoria is usually the explanation of this change. The following case will illustrate this principle. As in several instances before, the illustration is selected from a class of cases representing deviations greater than are properly included in heterophoria, because by these extreme cases the principle can better be shown than in such cases as are of less pronounced character.

Miss C. was examined first by me in March, 1881. She appeared at that time to have slight converging strabismus. Tests with a vertical prism showed homonymous deviation of 12° , and a screen placed before one eye caused that eye to deviate in. Changing the screen quickly to the other eye demanded from the eye just uncovered a movement outward for fixation. She had from childhood been slightly cross-eyed, the right eye deviating in, but she was able, within certain limits, to correct the appearance of squint.

Nothing was done at that time, and she was seen again, in January, 1889, nearly eight years later.

She now exhibited a diverging squint nearly as pronounced as was formerly the converging deviation. The right eye now appeared to float outwards, while the left habitually fixed the object. Covering the left eye, the right moved inwards in fixation. Changing the cover quickly, the left made a corresponding movement.

Tested by the phorometer she showed exophoria or esophoria, depending upon her will ; right hyperphoria 2° to 5° . After using a prism of 2° for right hyperphoria nearly a month, the extent of hyperphoria did not appear to vary much from 5° . February 11th tenotomy of the superior rectus of the right eye was made.

February 12th.—Hyperphoria, exophoria, and esophoria, each 0° . The appearance of strabismus had disappeared.

June 3d.—Still no appearance of strabismus. Hyperphoria 0° , esophoria 3° , with no deviation behind the screen. Patient had experienced great relief from certain nervous symptoms, which had previously been very annoying.

That the lesser tendencies of heterophoria not very unfrequently pass from esophoria to exophoria appears to be established by many observations.

From such facts we may reasonably conclude that great circumspection should be observed in respect to operative treatment of exophoria. All tests should be found to agree, and the question of a primary influence behind the condition of exophoria should always be settled before any resort is made to operative measures.

Resulting Symptoms.

The general symptoms of exophoria differ in some respects from those of esophoria. While the latter is more often the cause of pains in the head, in the back of the neck, at the seventh cervical vertebra, at a point between the shoulder-blades, and of many other more serious nervous disturbances, exophoria is more frequently the cause of asthenopia. Yet all the reflex symptoms of esophoria are to a certain extent common to exophoria. Among them are found some of the most important of the neuroses: epilepsy, mental disturbances, headaches, and neuralgia are examples.

Manifest or Latent.

In determining the extent of exophoria, it is important, as has already been shown, to exclude complicating tensions. If, by the phorometer, a certain extent of exophoria is indicated, if the abduction is in excess of 8° in proportion to the manifest exophoria, and if an important degree of hyperphoria is absent, we may assume that we have a case of uncomplicated outward tending of the optic axes. Even in such a case several examinations should be made to confirm this conclusion. The presence of exophoria being established, we have to determine approximately the extent. The manifest deviating tendency, as shown by the phorometer, no more indicates the absolute exophoria, than does manifest hypermetropia, as shown by the glasses of the trial case, indicate the total hypermetropia. In case of exophoria we may resort to the temporary employment of prisms for the purpose of revealing, approximately, the amount of the defect.

It is my custom to give temporary prisms of less than the full correcting power. The correction should fall behind the defect from one to several degrees. Should we make an absolute correction by prisms, we are liable to lead to an apparent defect, while, by following, we discover only what actually exists.

Treatment.

In slight or moderate degrees of exophoria very important relief to the asthenopia or even to some of the more serious reflexes may be secured by systematic exercises in overcoming prisms. Prisms of gradually increasing strength and with bases out should replace each other in rapid succession until the full extent of the patient's ability to overcome and unite images at twenty feet is reached. Commencing again with the lower numbers the prisms are again built up until diplopia cannot be corrected. Again and again the process is renewed during three or four minutes at a sitting. On the following day the patient will commonly accomplish the union of images with higher grades of prisms, and the exercises should be repeated from day to day until the union of images with prisms amounting to 50° is accomplished with ease.

In cases of doubt or in cases in which for any reason tenotomy is undesirable, this method is safe and often, at least temporarily, effectual.

Concerning the employment of correcting prisms, prisms with the bases in, what has already been said in speaking of the method of ascertaining approximately the extent of the defect, is applicable. Although accustomed to use many hundreds of such spectacles every year for such diagnostic purposes, I rarely find that they afford any considerable relief. Indeed, asthenopia and general uneasiness more frequently result from such prisms than does marked relief. Nevertheless, in a certain not very considerable proportion of instances, the prisms are restful, and important relief is gained.

Of all methods for the relief of exophoria the actual balancing of the opposing forces of the lateral muscles is

the only radical and permanently effectual cure. Tenotomy most frequently accomplishes this result. The method of performing tenotomy for these defects, of less extent than strabismus, has been described in the former articles of this series, and it is unnecessary to repeat the description here. It may, however, be well to remind the reader that a wound through the conjunctiva over the insertion of the externus leaves a much more conspicuous cicatrix than a similar wound over the insertion of the internus. Hence the greatest caution should be exercised to make the conjunctival wound the smallest possible. It should not exceed one half a millimetre in extent. Moreover, great care is required that the points of the scissors should, in making the opening, stand at a right angle to the surface of the membrane, thus avoiding even the slightest approach to a flap.

If a considerable effect is to be produced, this may be better accomplished by combining a very careful tenotomy of the externi with tendon contraction or tendon resection of the interni. The methods of making tendon shortening and tendon resection have been already described by me.¹

These operations have great advantages, in the class of cases under discussion, over operations for advancement such as have been previously described. For cases in which only a slight effect is desired, for example, when it is proposed to make a correction of two or three degrees, shortening by tendon contraction is sufficient. If, however, more considerable effects are to be obtained, tendon resection is required.

In making **tendon resection**, the proceeding which I have adopted is as follows:

With the narrow-pointed scissors used for subconjunctival tenotomy, which are figured in connection with the second paper of this series,² an opening is made in the conjunctiva less than one millimetre in extent and about a millimetre posterior to the insertion of the tendon and exactly over its central portion. The opening should be the smallest possible, not more than sufficient to expose a

¹ *New York Medical Journal*, March 30, 1889.

² See ARCHIVES OF OPHTHALMOLOGY, No. 2, 1888, p. 186.

small point of the surface of the tendon. The fine tenotomy-forceps¹ is then introduced, its branches closed, through this small opening and forced backward, when, by removing the pressure of the fingers, the expansion of the blades pressing against the elastic tissues surrounding them causes the opening to expand, thus temporarily enlarging the wound and permitting the operator to grasp, in the teeth of the forceps, a small fold of the tendon, slightly removed from its insertion. With much care the tendon is divided transversely, half a millimetre behind the insertion, carrying the division each way, as in the case of graduated tenotomy, until the border of the tendon is reached, which is to be preserved. As the division is carried toward the borders the section is more exactly on the sclera. The object of leaving a very narrow strip of tendon at the centre is to furnish support for the suture at a later stage.

With the fine traction-hook (Fig. 1) the central portion



FIG. 1.

of the proximal lip of the tendon opening is then drawn forward through the opening in the conjunctiva, which, without tearing, expands to allow of this procedure. While the tendon is thus held forward the small plow or divulsor (Fig. 2) is insinuated and pushed backward over all the parts



FIG. 2.

of the tendon behind the wound, effectually releasing the tendon from any connection with surrounding tissues.

This separation of the tendon will permit it to be drawn forward without causing so much of a fold of the conjunctiva as is otherwise likely to result if the tendon is much shortened. The tendon being now drawn forward to an extent equal to the amount of resection desired (and the resection must be made to conform to the extent of short-

¹ *Ibid.*, No. 2, 1887, p. 176.

ening proposed), either making traction by means of the traction-hook or by the fine fixation-forceps (Fig. 3), which

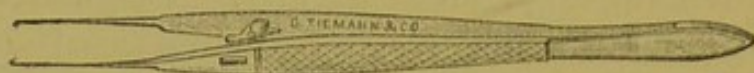


FIG. 3.

may be made to replace the hook, and using as much care as possible not to enlarge the conjunctival wound, a cut is made from each extremity of the transverse incision in the tendon backward so that the two cuts nearly meet just behind the insertion of the forceps. By this means a triangular piece of tendon is very nearly removed. Making traction now with the fixation-forceps, which holds the bridge at the apex of the triangle, the needle, armed with No. 000000 silk thread, is passed through just behind the apex of the triangle, when the resection of the triangle is completed. The needle is next carried through the corneal extremity of the tendon and the extreme border of the conjunctival wound, including, not to exceed one millimetre, when the suture is to be tightened and secured.



FIG. 4.

Figure 4 shows the needle-holder which I have devised with the view of avoiding the snap which is experienced from the ordinary forms, and with the view of having a needle-holder corresponding in delicacy to other eye instruments.

The object of the fixation-forceps is to maintain a hold upon the exact central portion of the tendon. Should resection be made without the precaution of thus securing this part, it would be doubtful whether the exact angle of the resected part could be readily found afterward. This may be done approximately, if the fixation-forceps has not been used, or if the hold has been lost, by carrying the slender hook beneath the tendon after resection is made, observing special care as to its direction so as to draw the angle forward. It is much better, however, to secure this point from the beginning, when it is possible to be very precise.

During the different stages of the operation, the conjunctival wound, originally very small, is in* danger of being enlarged by tearing or cutting, but this should, as far as possible, be avoided. The tissues are susceptible of a considerable degree of stretching, and what may during the operation appear like an opening of two or three millimetres will, after a few minutes, contract to a small point. The amount of tissue to be removed in the resection must, of course, as has already been intimated, be graduated by the effect desired. The surgeon should determine beforehand the extent to which it is desirable to change the relative position of the eye. The distance from the base to the apex of the resected triangle should correspond nearly to the extent to which the eye is to be rotated.

If the operation is made for the correction of the results of an excessive tenotomy previously made, and in which the insertion of the tendon has been allowed to fall back, the points of the scissors may, before drawing the tendon forward, be turned toward the cornea, and a pocket between the conjunctiva and sclera may be made. The needle, instead of passing through the corneal extremity of the tendon, may be carried further forward, and in returning pass again through the conjunctiva from without to within. Thus, on tightening the suture, the end of the tendon is drawn forward into the little pocket.

In making **tendon contraction**, the conjunctival opening is made as already described. Then the tendon is drawn slightly forward through the opening and is cut transversely toward each border. The small traction-hook is then introduced beneath the tendon, which it draws forward. The needle is carried through the tendon as far back as necessary. If it is carried so far back as to leave in front of it any considerable extent of the tendon, this may be shaved off by the scissors so as to leave a very thin border. The needle is then carried through the anterior lip of the tendon as has already been directed, and the suture secured as before. Before finally tying in either case the patient should be tested in respect to the result, when, if it is excessive, the suture may be loosened before the knot is

secured, and, if insufficient, the operation can be carried further.

No extensive cicatrization occurs after such operations. The tendon is not bound to the sclera or to the conjunctiva. Union takes place by first intention, hence there is very slight prospect of losing the result of the operation, although, owing, to the elasticity of the parts included in the suture, an excess of effect should be temporarily induced. Owing to the extreme fineness of the thread, no inflammation is set up about it. It may be removed after five or six days, or it cuts its way out without assistance. A few weeks after such an operation only minute traces of it can be discovered. No unsightly scar and no adhesions are left to remind the patient or the surgeon that an operation has been done.

VI.—SOME CONSIDERATIONS RESPECTING THE DEVIATIONS OF STRABISMUS AND THEIR TREATMENT.¹

From the time when John Taylor went from city to city in Europe advertising the cure of strabismus by operation, to the time when the Academy of Sciences of Paris awarded the grand prize to Strohmeyer and Dieffenbach, to the one for the suggestion, to the other for the execution, of the operation, which had already been practised a century before by the itinerant oculist, the correction of squint was in the hands of the charlatan only.

From 1840 to the time of the important contributions to the subject by Donders and von Graefe, progress had indeed been made, yet even at this time a large proportion of respectable oculists preferred to permit their patients to endure the defect of strabismus rather than risk the deformity of the then so frequent over-corrections.

The method of making the section through the tendon near the sclera instead of making it in the course of the muscle, marked a great advance in the history of the operation. The investigations of Donders respecting the rela-

¹ This general section was read under the above title at the meeting of the AMERICAN MEDICAL ASSOCIATION at Newport, June 26, 1889.

tions between strabismus and refractive anomalies was another important step in the theoretical knowledge of this interesting subject.

Since these signal additions to the knowledge of strabismus, it cannot be said that any remarkable progress has been made by the profession at large, and it is safe to say that the theory and the practical management of strabismus remain very nearly where Donders and Graefe left them more than twenty-five years ago.

The subject in many of its bearings remains still obscure, and still the operations are made mainly for cosmetic purposes.

Rightly understood there is perhaps no department in ophthalmology which demands a wider range of study, or which will afford more gratifying results to scientific labor than these anomalous relations of the visual axes.

The lines upon which theoretical research and practical procedure must advance appear to me to be, first, a more systematic examination and appreciation of the unequal tension of the muscles, in every possible relation, than has hitherto been usually demanded; what is needed is not so much the addition of new facts as the better interpretation of facts already at our hands. Second, a well directed attempt in every instance to establish not simply cosmetic improvement but binocular single sight in the whole range of ordinary vision. This last part of the proposition is to be emphasized. The attempt is to be made, not only to establish binocular sight, but binocular seeing in the whole range of ordinary vision. The second part of the proposition depends upon the first.

The first of these lines of research appears to me to demand a change in the procedure of examination. Not that radically new means are required, but that a more systematic and thorough employment of known means should replace some loose and thoroughly unscientific methods long in vogue. Donders has already taught us to examine the refraction; there are many other details for us to study before we understand even the simplest of strabismic cases. Beyond question it is all too common for the surgeon to

proceed to sacrifice the continuity of a tendon in a perfunctory manner without having made adequate examination of the relations of the organs upon which the operation is to be performed, and without due consideration of what will be the resulting loss of motility of the eye subject to his operation, or of what will be the precise relation of this eye to its fellow when the supposed cure is completed.

If we ask ourselves what real technical information is gained by the methods which are laid down in our ordinary text-books for examination in strabismus we shall find it inadequate. It should be admitted without discussion that the precise relations of the visual axes to each other, measured not in linear measure but in angles and in every possible relation, must be determined before we can possess any sufficient knowledge of the necessities of a given case. Rightly considered, what could be further from a correct method than a determination of the deviations of visual lines by linear measure? The delicacy of balancings inwards and outwards, upwards and downwards, cannot by any possibility be estimated by any such method. Strabismus is rarely a simple condition. That this observation does not conform to the generally accepted view appears to be shown by the fact that it is rare to find a case which has been treated by operations for any but the simple conditions of convergence or divergence, or, with rare exceptions, for vertical deviation.

Determination of the Relative Tensions.

In order to proceed successfully towards the attainment of perfect binocular single vision, we must become fully acquainted with the details of the relative tensions of the various muscles of the two eyes. Nothing but a knowledge of the relative positions of the respective images of the two eyes will serve in this respect. The first step then in the process of an examination in a case of strabismus is to determine this point. To do this, in many cases of concomitant squint, is no easy task. Indeed it is believed by many that it is impossible in a certain number, if not in a great proportion, of instances in which considerable deviation

exists. Contemporary literature shows that this belief is very prevalent, and that in the majority of cases no measurement beyond the linear is attempted to be made.

My own experience leads to the belief that the proportion is quite small in which diplopia cannot be made manifest to the patient. Great patience and some skill are frequently demanded in these cases. It is not an infrequent experience that a strabismic patient is required to make long-continued trials, day after day, for a whole week, and in some instances for even a longer period of time, for the single purpose of learning the position of the double images. The patient often meets my assurances that he or she is seeing double images with the most emphatic counter-assurance that he or she does not see double images of the same object, and that it is useless to attempt to convince one of a physical impossibility. A kindly encouragement that, with patience, the surgeon and the patient will at last understand each other, with possibly some explanation of what is expected, induces the patient to persevere in the effort. The room is darkened, a lighted candle is at the farther end, a red glass is placed before the best seeing eye, and then prisms to change the position of the images in all directions are used. With every change of prism, or of the colored glass, the patient is told what change is made in the relation of the images. This process is continued for twenty minutes or more, and repeated day after day until success at last crowns the effort. Perhaps after repeated sittings the patient, in the midst of one of these trials, suddenly exclaims: "There, I see two now, but I know that I have not seen more than one before." This remark is a surrender. Little difficulty occurs after this first discovery.

The next stage of the examination is the determination of the actual balancing of the muscles. One who has not practiced this form of examination habitually will be astonished to find how few of his cases are simple convergent or divergent strabismus. A recent text-book on ophthalmology says: "We often find, along with a pronounced lateral deviation, a slight deviation upward or downward." No practical deductions are made from this proposition, and

one has only to glance over the statistics of operations in the various eye hospitals, and to read the current literature of strabismus, to learn that these "slight deviations" are rarely taken into account.

It will perhaps be thought to be an extreme statement when I declare my belief that the search for these upward and downward deviations is of vital consequence in every instance, and that in general they should receive first attention in the treatment of the case.

In the practical examination of any case (vision existing in both eyes) we are to assume that in every instance in which the axes of the two eyes are not in normal relations diplopia exists. This proposition is denied by Schweigger and others. I shall not here enter upon a discussion of the merits of the proposition, but shall proceed not only upon the basis of its truth, but shall further insist that not only are we to assume the presence of double images, but that before we proceed to a final correction we are to find these images in the relative positions in which they should be according to the theory of identity—that is, the theory that objects appear single when their images fall upon identically corresponding parts of the two retinae, and that they are double when the images fall upon points not corresponding.

To the end that we may locate these double images in every instance, we may properly divide the cases of strabismus into two very general but not well-defined classes—the moderate and the extreme. Between these classes there is of course no actual dividing line, and the classification is simply one for convenience. In the moderate cases the presence of diplopia can, as I believe, in every instance be made out. In cases of extreme deviation the difficulties are often great and the time required to demonstrate the diplopia might well be spared. Indeed the patient might after long-continued efforts refuse to acknowledge the presence of diplopia. For convenience we will discuss the method of examination first of the class of moderate deviations and then pass to the other class.

The tests by the perimeter which are described in some of the text-books, do not appear to me to be of sufficient

accuracy to serve the purpose of determining the relations of the visual lines for the practical purposes of treatment. A method of perimetrical examination described by myself at the International Medical Congress at Washington in 1887,¹ is more satisfactory, but even this method is better adapted to cases of paralysis than to ordinary cases of concomitant squint.

I find that the use of prisms, first to determine the deviations from the horizontal plane, then from the vertical and finally in complex directions, serve the best purpose. It is often desirable to place a red glass before one of the eyes, preferably before the one most used in fixation, and then to proceed by the use of prisms to ascertain to what degree one image falls below or rises above its fellow, then in the same manner to determine the extent in degrees of the deviation in a lateral direction. When enormous prisms are required for the lateral displacement of the images, the determination becomes less and less satisfactory so far as the degree of deviation is concerned. Fortunately this is not of vital importance, inasmuch as beyond a certain point tests of this description are only of approximate value. In moderate cases only can a fairly accurate determination be made. Next, tests are made by means of the phorometer, permitting a comparison to be made between the results obtained by the two methods. The phorometer can of course be of service only in cases of moderate deviation. The comparative power of the various muscles in rotating each eye in adduction and in abduction, in sursumduction and in deorsumduction should be thoroughly tested, not in reference to the co-ordinate movements of the two eyes, for these are not established, but in reference to the movements of each eye independently. This determination of the relative mobility of the two eyes, inward and outward, in cases in which strabismic operations have already been made, is of a special consequence. The comparative extent of rotation must often serve as guide to all of our procedures. The movements of the eyes should then be carefully observed while a screen is passed first before one and then

¹Transactions Ninth International Med. Cong., 1887, vol. iii., p. 735.

before the other, and while the patient is directed to fix a distant object—for instance, a lighted candle. Not only may we observe the movement of the eye as it passes from its passive state to the state of direct fixation, but we may learn something from the patient respecting his consciousness of the change of position of the image as the eye comes into position of fixation. The precise direction of this apparent movement of the object as seen by the patient may sometimes, though rarely, be an aid in determining the direction of deviation.

It must not be supposed that these various tests will always prove satisfactory or uniform. Indeed the incongruity of tests is not unfrequently a source of perplexity to the surgeon. Thus in regard to the diplopia tests, it is not rare that in a case of marked divergent strabismus in which the examiner naturally looks for crossed double images, distinct homonymous diplopia will be found, a condition only to be expected in convergent strabismus. Such contradictions are by no means rare, and the investigator who is not prepared to find them and to interpret them will find himself in an embarrassing position if he is attempting to do exact work. Further on, cases of this character will be reported in illustration of these perplexing conditions. Again, movements apparently outward and inward behind the screen are not unfrequently in reality only the effect of a swing depending upon the unequal tension of the superior and inferior recti. Indeed a considerable number of cases of apparent converging or diverging strabismus are neither the one nor the other, but are cases of vertical deviation made lateral by the strong instinct of the patient to relieve a vertical diplopia, and in such cases the habitual tension of the muscles continues in many instances even when one of the eyes is concealed by the screen. The true relation of the muscles may not be revealed at first, and in such cases only the most careful deductions from all the facts ascertainable by all the various means of examination after repeated trials should be accepted as the correct interpretation.

Tests for binocular vision or for the deviations of the axes should also be made at near points. All the preceding tests

should be made at a distance of not less than twenty feet. For the near tests, the distance may be selected according to the circumstances, within a range of from a few inches to one or two feet in advance of the eyes. These tests at near points should always be regarded simply as checks upon the tests at a distance. They may call our attention to certain conditions which would not otherwise be observed, but tests at near points should never be made the basis of treatment. The use of such tests in forming a conclusion in regard to the actual deviations will be illustrated as we proceed.

After the patient has been well trained in the recognition of diplopia, a brilliant point—for instance, a small opening in a dark-colored card held between the eyes and a strong light, or some object chosen for its strong contrast with its surroundings—will in general serve the purpose at the near point. The stereoscope has been extensively used and is of much value when the objects seen are not ordinary pictures but diagrams complete only when blended under the influence of binocular vision.

Allusion has already been made to the phenomenon of double images appearing in positions relatively different from those in which, considering the character of the deviations as judged by the appearance of the eyes or the movements of the eyes when passing from the position of passive repose behind a screen to active fixation, we should expect to find them. This phenomenon has been one of the strong arguments that binocular vision may exist in actual squint, as the images do not correspond with the theory of identity. An explanation of this state of things not unfrequently involves great difficulties. Patient observation will, however, often help to solve the question. In a certain proportion of instances an explanation, perhaps not altogether satisfactory, of this anomalous condition can be found in the change that is made in the position of the eyes in alternate fixation. One axis and then the other turns towards the object, and the resulting impressions seem to constitute a sort of mental adjustment resulting from these alternate physical efforts.

In another and larger proportion of cases not the slightest

change of direction of the axes of the eyes can be detected by the observer, while the patient gazes with both eyes uncovered, even when the most careful scrutiny is made. Both eyes of the patient appear to be immovably fixed, and still this anomalous diplopia occurs. The phenomenon is, most frequently, the expression of a decided preponderance of some of the muscles which act in the vertical direction over their more immediate opponents. That is to say, it is an expression of hypertropia. In a smaller number of instances it is the expression of a decided difference in the rotating action of corresponding lateral muscles; for instance, the difference in the rotating power of the two interni after an operation for converging squint when the severed tendon has been well "set back." Cases of this latter class are among the most perplexing of all the varieties of strabismus.

It may be generally stated that the presence of these anomalous forms of diplopia should suggest the condition of a strong tendency, or an actual deviation, of one visual line much above the other, or of greatly disproportionate rotating power of corresponding lateral muscles. Unless some other causative condition can be discovered, one of the above states should be assumed, unless it can be positively disproved.

Thus far we have considered the method of investigation in cases sufficiently moderate to permit of practical use of diplopia tests. There is a large class of extreme cases in which diplopia tests can either not be made, or in which they can afford little information. It is my custom, after as careful examinations as I can make by observing the various movements of the eyes, to proceed, not to a correction of the strabismus, but by operation to convert an extreme case into a moderate one. This may be done by one or more operations. Such operations may be required on one and then on another lateral muscle, or upon a vertical and then a lateral muscle. The object is to approximate the visual axes sufficiently to enable the patient to acquire such a knowledge of the positions of the double images as to form a guide for subsequent treatment.

Systematic Classification.

We are met at the outset of these examinations with a practical, although by no means essential, difficulty in classification. When we have succeeded in ascertaining a certain amount of deviation from the horizontal and vertical planes, we have scant means of expressing these results except by a full description in many words. A system of terms to express these deviations of strabismus similar to that which I have suggested for the lesser degrees of deviating tendencies¹ appears to me a not unimportant element in the study of strabismus. Had I not already proposed one such system of terms, I should feel perhaps less hesitancy in offering one for these conditions, but the importance of a more systematic method of description, and one which shall be in harmony with that already proposed for the lesser tendencies, must be my excuse for a further extension of this system of words. The word employed as the central idea for terms to express the faulty muscular tendencies less than actual deviations was *φορά*,² a tending. Hence we had the words, Orthophoria, Heterophoria, Hyperphoria, Esophoria, and Exophoria; expressing respectively, parallelism of the visual lines, the absence of such parallelism, a tendency of one of the lines above the other, a tendency of the lines inward, and a tendency of the lines outwards. Combining certain of these terms we may represent complicated conditions, as, for instance, hyper-esophoria, indicating a tendency of one of the lines higher than the other, and also a tendency of the lines inward.

If now we adopt the Greek word, *τροπός*, a turning, for the basis of terms for the more extreme conditions of actual deviation of the visual lines, we shall have a corresponding system of terms, as follows:

HETEROTROPIA, the general statement of deviation.

HYPERTROPIA, the deviation of one visual line above the other.

¹ *New York Med. Jour.*, Dec. 4, 1886. ARCHIVES OF OPHTHALMOLOGY, No. 2, 1887.

² Improperly printed in former number, *φορος*.

ESOTROPIA, the deviation of the visual lines inward.

EXOTROPIA, the deviation of the visual lines outward.

Compound terms are formed in a manner similar to that employed in the former system of terms.

Practical Application of Principles.

We may now consider the practical application of the facts ascertained by such an examination as we have outlined.

Should we find the images in the same horizontal plane, and agreeing in relative position with the theory of identity—that is, if we have with converging deviations homonymous, or with deviations outwards heteronymous diplopia, we have next to inquire whether at the near point the conditions correspond with those at a distance. If not, we are not to accept the result, but to search further for the cause of the contradiction.

Illustrations of the disregard of this principle may be found in some of the best works on the subject of squint. If at a distance we have homonymous diplopia while the images cross at a near point—that is, at a point further in advance of the eyes than the ordinary near point of convergence, we may well doubt the diagnosis of simple converging strabismus. In simple converging strabismus the convergence for near points is nearly always in excess. Rare exceptions to this rule should only be accepted as exceptions after the most conclusive experiments. In such cases we are to be on our guard for hypertropia. The tendency to deviate in the vertical direction may be concealed, but it is rarely, in such cases, absent. Should the images not be found in the same plane, this condition should, as a rule, receive first attention. Exceptions to this rule will occur to the intelligent surgeon. Thus, should the vertical deviation be very slight while the lateral deviation is great, at least a partial correction of the lateral squint may first be made. The correction for the vertical deviation, should it still exist, may then follow, and finally the complete correction of the lateral deviation. The end to be attained is perfect binocular vision in the

whole range of sight, from the near point to infinite distance. A single operation can rarely accomplish this, and it is more creditable to the surgeon that he advance by several very cautious steps toward the end so greatly to be desired, than that he should make a brilliant though less successful leap.

The method of investigation and of procedure in such cases I cannot better describe than by the following illustrative case, which is a typical one of a large class.

Miss H., aged 30, a lady of superior intelligence, and able to describe what she saw, was first examined October, 1888. She had always been strabismic, having at the time of her first visit a very marked diverging squint. She was able to fix either eye separately at will. The left eye appeared to fix more frequently than the right, but she sometimes changed the eyes while looking at an object without thinking of the change. While fixing an object at twenty feet distance with either eye, the other deviated outward more than two thirds of the diameter of the cornea. After a half hour of attempts made in a darkened room, and with every known device for inducing the recognition of diplopia, she was quite unable to become conscious of double images. On admitting the light to the room, and studying the relative movements of the eyes in alternate fixations, a small screen being passed quickly from before one eye to before the other, thus causing alternate fixation, and observing the eyes with the greatest care, as nearly as could be ascertained, after many trials, the eyes appeared to move exactly in the horizontal direction. Not the slightest vertical deviation could be detected by myself or by my assistant, Dr. Boyer. On the third day, after a long sitting, and with much patient and intelligent effort on the part of the lady, she was able to recognize the double images, if a partial correction of the relation of the visual lines was made by placing a prism of 20° with its base inward, before one of the eyes, or with a prism of 10° similarly placed before each eye. That this correction did not neutralize the deviating relations, was shown by the fact that still while using the prisms, either eye deviated outward behind a screen, and that if a screen was passed from before one over before the other eye, the uncovered eye was forced to make an excursion inward of more than half the diameter of the cornea in fixation. With such a prism, and with a red glass before one eye, the patient now

realized diplopia for the first time, but not with crossed images, as might have been expected; the images were homonymous. They could not be made to unite by the help of any prism or combination of prisms. There appeared, however, with this arrangement, to be left hypertropia of 6° or more. This condition appeared to be pretty satisfactorily determined, for the action of prisms in this direction was very prompt and decided. On the succeeding day, after a very careful study of all the phenomena, and finding them substantially as before, it was determined to make a partial correction of the diverging squint. Tendon resection of the internus of the right eye was made. Immediately after this the deviation appeared to be about one third corrected, and there was still homonymous diplopia. Five days later the left eye was treated in the same manner as the right had been, and the eyes appeared in much better relation, but still with moderate outward deviation. Homonymous diplopia still existed, with left hypertropia of 5° or 6° .

On November 23d, after several examinations had been made on different days, and after much time had been spent in carefully locating the images and comparing the relative rotation of the eyes, it was found that with a prism of 8° , base up before the right eye, or base down before the left, the images were satisfactorily in the same plane (showing left hypertropia), when suddenly she obtained crossed diplopia for the first time. A prism of 10° , with its base in, now united the images. We had, therefore, as nearly as could be determined, left hyper-exotropia $8^{\circ} \perp 10^{\circ}$.

Tenotomy of the superior rectus was then made, which appeared at the time exactly to correct the hypertropia, but it was found on the following day that there was a slight over-correction. By means of a suture the effect of the operation was modified, and the images were again in the same plane. Crossed diplopia was now constant whenever the red glass was used, and on December 11th a further careful tendon shortening of the left internus was made. From this time there was no heterotropia, but there remained heterophoria. A moderate right hyperphoria and exophoria demanded, for accurate adjustments, very careful operations for shortening the superior rectus of the left eye, and then for relieving the tension of each of the externi by graduated tenotomies.

Single vision was fully established in the direct line at all ranges between four inches and infinite distance. At present if she looks

far to either side, slight diplopia occurs. This, however, is becoming less and less noticeable as the tendons regain their flexibility, and it will doubtless wholly disappear after a few months.

The plan which was adopted in the case just related may be wisely adopted in the class of extreme deviations either of divergence or convergence. The extreme deviations may first be reduced by operations, which shall not disable any muscle, to moderate deviations, in which the double images can be recognized. From this point the more accurate and final adjustments may be made.

Antipathy to Single Vision.

I have referred to the fact that in the early stage of the examinations in the case which I have above related, after the ability to recognize double images was established, there was no possibility of uniting these images by prisms. Even after the divergence had been reduced to a very moderate extent, the images still refused to unite under any circumstances until a correction of the left hypertropia had been made. Had a full correction of the outward deviation been made by free tenotomies of the externi, we should have had, without any doubt, an illustration of the condition which was termed by von Graefe "antipathy to single vision." However this may be, my experience leads me to believe that by procedures carefully made in every instance this so-called "antipathy to single vision" may be eliminated. This peculiarity has been located, by various authorities, in the brain or in the faulty projection of the image from one retina or from both retinae. Schweigger, speaking of this class of cases, in which only slight deviations exist and yet in which the patient cannot be made to see single, remarks: "Binocular vision does not exist even for distance. The reason does not lie in the impossibility of fixing the same object simultaneously with both eyes, for the objectively proved deviation may be extremely slight. A union cannot be obtained even with prisms. If crossed double images are present close together, a prism of a few degrees base inward suffices to make them homonymous."

It is with no disrespect to the great authority of von Graefe that I declare my entire disbelief in any theory of physiological "antipathy to single vision." Such a phrase rightly interpreted means inability on the part of the surgeon to discover the real relations of the eyes. Patient search and accurate procedures will in nearly every instance resolve these cases of antipathy to single vision into cases of accurate binocular seeing, and the exceptional cases probably depend upon the failure of the surgeon rather than upon any intrinsic anomalous condition of brain or retina of the patient.

It is not to be inferred that with our present knowledge of methods of diagnosis and of treatment every case of inveterate diplopia of this class will yield to our efforts, but the state of mind on the part of the surgeon which frankly concedes his own limitations of knowledge is far more favorable to success than that which relegates his case to the region of the impossible. Many interesting cases belonging to this class might be adduced in illustration of the views here taken, were it consistent with the scope of this paper.

Evil Results of Unequal Rotation.

Among the cases of double vision which I encounter frequently, is a class in which converging or diverging strabismus has been supposed to exist, and for which full tenotomy on an internus or an externus has been performed, crippling the eye in its rotating movements, sometimes giving it a goggled appearance and leaving diplopia. The discovery of hypertropia in many of these cases leads to the strong suspicion that there may never have been any very important lateral deviation, that the swing from the hypertropia gave rise to an apparent convergence or divergence for which the operation was made. Such operations on the lateral muscles leave the patient with possibly less appearance of squint, but with far worse optical conditions than before the operation was done. Indeed, a not uncommon cause of difficulty in obtaining perfect single vision at all ranges is the restriction of rotation of the eye which has been subject to the standard operation for strabismus. I think that I hazard little

in saying that the operation for strabismus as described by von Graefe, and in the text-books of ophthalmology generally, is incompatible with complete binocular vision. Graefe states the proportion of binocular vision obtained by him at fifty per cent., but when we examine the methods by which binocular vision was determined by him it is reasonable to doubt whether these figures express any thing further than the ability to fix the eyes upon some given point for the moment only. Statistics, which do not state the range and all collateral circumstances respecting binocular vision in such cases, possess very little value.

A truth which cannot be too strongly presented, although in direct conflict with the teachings of von Graefe and later authorities, is embodied in the following maxim :

Every modification of the length of a lateral muscle, by relaxation or by shortening, which can in any degree effect the rotation of an eye, must in every instance be accompanied by an exactly equivalent modification of the corresponding muscle of the other eye.

The precept universally taught, that a moderate strabismus can be effectively treated by the setting back of a single muscle is entirely inconsistent with any system of ballancing of the opposing eye muscles, or of establishing perfect binocular vision.

Equally prejudicial to perfect results is the practice of making an extensive setting back of one muscle and a moderate or slight setting back of the corresponding muscle of the other eye.

Nor can the setting back of one muscle and the advancement or shortening of its immediate opponent of the same eye be expected to result less unfavorably.

General Principles Restated.

The principles to which I have desired to call attention in this section may be briefly stated as follows :

1st. Results of examinations for strabismus should be expressed in angles and not in linear measurements, these latter being unscientific, misleading, and often pernicious.

2d. To this end diplopia must be recognized and the

double images carefully located. In all cases of moderate strabismus, with patient and intelligent effort continued for a sufficient length of time, such recognition of diplopia can be obtained, and the relations of the visual lines can be studied. Extreme cases of strabismus may first be converted into moderate cases for better observations, but in no case should a full correction be attempted until the relations of the visual lines have been carefully observed.

3d. For the accurate expression of the various deviations of strabismus more systematic terms are desirable. The terms here proposed are in harmony with those proposed for the anomalous tendencies less than strabismus.

4th. The relative position of the double images is sometimes contrary to well-known laws, and, unless the surgeon is on his guard, may be misleading. These exceptional positions of the images should lead us to the conclusion that the case is probably one of hypertropia or of disability as the result of operation. In such cases, before any considerable lateral correction is made, the hypertropia, if existing, or the disability from the displacement of the attachment of the tendon if that condition is found, should receive attention. Slight lateral correction may sometimes be required before the degree of hypertropia can be determined with sufficient accuracy to admit of a correction.

5th. The unequal tension of the two pairs of superior and inferior recti is often responsible for an apparent converging or diverging strabismus, and in many such cases cures are attempted by operations on the lateral muscles, which leave the cases in conditions worse than before the operations. The study of hypertropia, if not the most, is one of the most, important elements in the examination of any case of strabismus.

6th. The traditional "antipathy to single vision" is not a physiological fact, but a phrase expressing only the inability of the surgeon to interpret the meaning of the double vision. By relieving the tension of hypertropia, by equalizing the rotating power of corresponding lateral muscles, or making some other necessary correction, a very large proportion of such cases is either cured or resolved into cases of simple and uncomplicated strabismus.

7th. The standard operation for strabismus, by reason of its disabling effect upon the severed muscle in the performance of its office in rotating the globe of the eye, and by reason of the vastly unequal rotating power of the two corresponding muscles resulting from that operation, is an obstacle to a perfect result ; and the effect of the ordinary strabismus operation must be regarded as of cosmetic rather than of optical value.

8th. Graduated tenotomies in which no tendon is disabled from performing the full required rotation of the eye, combined with tendon resection of the opposing muscle, operations if need be to be made on several muscles instead of on one, should supersede the method of raising a tendon on a hook and severing it completely.

9th. The correction of squint, with the view of obtaining perfect binocular vision throughout the whole range of vision, instead of being one of the easiest of surgical operations, is a procedure demanding the supreme ability of the accomplished observer and the highest skill of the dexterous operator.

ANOMALIES OF THE OCULAR MUSCLES.

[FOURTH PAPER.]

By DR. GEORGE T. STEVENS, NEW YORK.

VII.

AN EXAMINATION OF VON GRAEFE'S DOCTRINE OF "ANTIPATHY TO SINGLE VISION."¹

IN Von Graefe's classical description of the condition to which he applies the term "Antipathy to Single Vision," he says: "It has sometimes happened to me that after squint operations with apparently correctly adjusted visual axes there have resulted double images only slightly removed from each other. The visual power of each eye has been quite good, alternating strabismus having previously existed, and the accommodative power has been similar in the two eyes. Nevertheless it has been in no way possible to bring about single vision."²

He states that this condition of double seeing persists notwithstanding the interposition of prisms in various positions, and that every effort of the patient to unite the images results only in removing them to still greater distances.

He adds: "The tendency appears to be a direct physiological contradiction; for while in sound eyes some approach, especially in case of large retinal pictures, is sufficient to induce arbitrary muscular contraction in the interest of single vision, in these cases, on the other hand, it is found that

¹ Read at the meeting of the American Medical Association, May, 1891.

² *Arch. für Ophthalmologie*, i., 1, 117.

exactly the opposite condition prevails, there being an absolute incompatibility to single vision."¹

In a still later article² he describes the condition more at length, pointing out the fact that the double images, although not far removed, pass from one side to the other, above and below, or one behind the other, always on the point of uniting, but never united. Von Graefe explains the anomaly on the theory, first, of injury to the nervous centres or faulty projection from the retinae, and, second, of the supposed difficulty of obtaining regular associated action between muscles which have long been unaccustomed to association.

A careful examination of many of these cases of "antipathy to single vision" leads me to conclusions different from those arrived at by von Graefe, and the practical application of these conclusions has shown that they are, at least in a great measure, correct. That, in a proportion of these cases, the technical details of disturbing elements may elude our search is undoubtedly true, but that the principles which I shall present will apply very generally I am fully convinced.

In a paper read before the American Medical Association, June, 1889,³ I have already expressed my disbelief in the generally accepted view of the existence of a physiological antipathy to single vision, and my conviction that, by properly selected and properly executed proceedings, this unpleasant condition may usually be eliminated.

The view of the causation of this anomaly, as set forth in that paper, may be briefly condensed into a single sentence.

The condition of antipathy to single vision as described by Graefe and by subsequent authors depends not upon lesion of the brain or faulty projection of the images from the retinae, but upon unequal tension of corresponding ocular muscles under the influence of corresponding nerve impulses directed to them.

I do not assert that no irregularity in projection from the retinae can occur, nor that cerebral lesions may not induce

¹ *Arch. für Ophthalmologie*, i., 1, 118.

² *Arch. für Ophthalmologie*, iii., 1, 119.

³ Published in *ARCHIVES OF OPHTHALMOLOGY*, vol. xviii., p. 371.

incurable diplopia. Such cases, if found, will present other and more definite phenomena of the existing ocular or central nervous disease than simply the presence of diplopia. The proposition refers to the cases which come fairly within the class so clearly described and so sharply defined by Graefe.

Excluding then, cases of paresis, and confining ourselves to the class of cases thus defined, we shall find the causation of this supposed antipathy mainly in two conditions. The first of these is acquired as the result of the squint operation or operations. It consists in the fact that by unequal settings back of the insertion of the corresponding tendons, there are induced irregular responses to the impulses directed to these corresponding muscles. In the examination of a very large number of cases, I have found this condition, but generally modified by a second to be mentioned presently, by far the most prevalent. There will be found in such cases either an excessive rotating power, or a power of rotation only moderately restricted, of the muscle of one eye, internal or external rectus, while the rotating power of its direct associate of the other eye is materially restricted. As a consequence of this irregular and unequally balanced condition of opposing muscles no harmonious adjustments can be made, and the more earnestly the patient strives to bring about associated action, the more signally he fails.

That "settings back" of the ocular muscles to an unequal extent may be made with propriety and with success, was taught by the great master, von Graefe, himself, and the practice has been very generally continued to the present time.

It is true that von Graefe advised in extreme cases a division of the operation between the two eyes, but in fact, this was a concession only to most obvious disabilities involved in the failure of the most conspicuously associated movements toward the side opposite the eye operated on, if in a case of converging strabismus, and an impediment to even approximate convergence at near points. Within the limits of extreme results a full correction of the appearance of squint was, according to his teaching, not only permissible

but desirable. This proceeding of making a correction of squint by a single operation has been supposed to be sustained by the theory that the muscle of the squinting eye is pathologically shortened to a considerably greater extent than its antagonist.

It may be conceded that there is, within certain limits of unequal tensions of accordant muscles, a possibility of union of images; otherwise binocular vision would in no case be established except when exact balancing of the tension is secured. That easy and permanent associated action is compatible with any considerable degree of diversity of tension, I do not believe.

It may be objected that if this proposition is correct the proportion of perfect corrections for squint by the prevailing methods of operating must be less than is ordinarily supposed. It is probable that examinations made by methods more exact than those which have been ordinarily employed would show that a very large proportion of cases in which binocular vision has been presumed to have been established by the ordinary squint operation is much smaller than is commonly supposed. However this may be, whether the results of the standard squint operation is often successful or not, it is certain that such unequal tensions are in many instances incompatible with a blending of the images.

A second causative influence, and one which acts as an element in nearly all of these cases, is the difference in relative tension of muscles which act in the vertical direction.

The instinct of bringing images to the same horizontal plane appears to be very great and only second, if indeed it is second, to that of union of images. In case of double images, whatever the difficulty of blending may be, the patient instinctively exerts his best endeavors to place the images in the same horizontal plane. It thus happens, that in certain cases in which, either with or without slight lateral inequality of tension, the effort to bring images to the same plane induces a lateral squint,—a squint which may be variable; that is, such a squint may at one period of life be converging, and at another diverging. Thus, in a case now under my observation, the patient was, during her child-

hood, subject to a very pronounced converging squint. During the past twenty years she has had conspicuous diverging squint, although no operation has been made. Such a condition may properly be called *variable strabismus*, its character of divergence or convergence changing from time to time, remaining possibly in one direction during several years, then changing to the opposite direction.

If in such a case one or both interni or externi are cut, double vision of an intractable form is likely to result. In such cases we must make diligent search for the vertical deviation, a condition often obscure or not at all manifest, before we can succeed in establishing binocular vision.

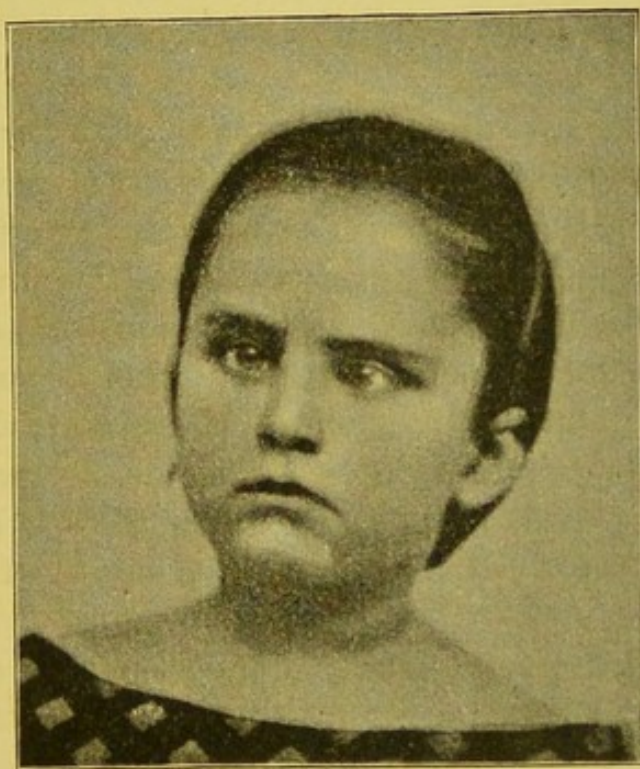


FIG. 1.

I have had the good fortune to obtain a daguerreotype portrait of the lady whose case has just been mentioned, taken during her childhood, and from which I have made an enlarged photograph which I have the pleasure of showing (Fig. 1). The photograph shows converging squint, so pronounced that few ophthalmic surgeons even at the present day would hesitate in regarding it as a proper case for a free division of the internus of one, if not of both eyes. Had

such an operation been performed upon this patient in early life, intractable diplopia would doubtless have resulted, and eventually extreme diverging strabismus. In another photographic portrait of this lady, made by myself a year ago (Fig. 2), a moderate appearance of diverging strabismus is seen.



FIG. 2.

In fact a divergence of more than 12° with corresponding crossed diplopia existed. But the most striking feature suggested by this photograph is the left hypertropia, well defined in the position of the eyes and of the brows. The question at once arises whether the change from converging to diverging strabismus is not the result of some radical change in the static condition of the eye-muscles. That this is not the case will be seen by the most cursory glance at the third portrait (Fig. 3), in which the old converging squint has returned. This condition of convergence can be

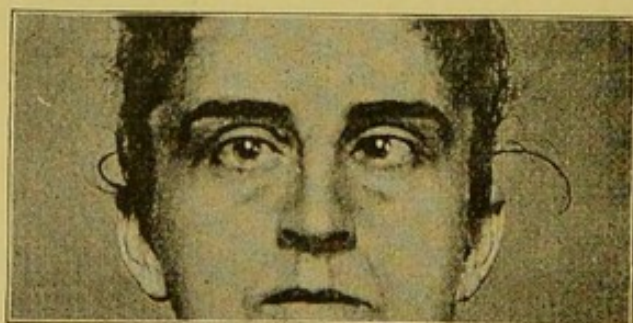


FIG. 3.

induced at any time by the application of a solution of atropine to the eyes. At the time of taking this third portrait, atropine had been applied twice a day for three successive days, and its effects were complete. A week after

that time the diverging squint had returned and has continued during the year. The transformation from divergence to convergence occurs within an hour after the first application of the atropine, and the present habitual condition of divergence returns as soon as the effect of the drug passes off. This variableness is, without doubt, due to the action of the muscles in the effort to overcome the unequal height of the images, and until the condition of the hypertropia is eliminated such changes of the lateral relations are liable to occur. In passing, a single thought may be given to the adverse testimony of such cases to the well-known doctrine of the relations between the excessive efforts at accommodation and converging strabismus; for here the converging strabismus occurs only when accommodation is neutralized. The present interest in the case centres in the fact that had a free tenotomy of an internus been practised during childhood, the almost certain result would have been an "antipathy to single vision." Even at the present time, when the conditions of hyperphoria and hypertropia are carefully sought for, this patient is able, under many circumstances, to conceal completely the evidence of hyperphoria as shown by the phorometer.

A curious fact in connection with the inequality of tension of the lateral muscles associated with hyperphoria is that a condition which in a passive state of the muscles of either eye or of both eyes is a marked divergence, becomes, as soon as all the muscles are engaged in the act of adjustment, pronounced convergence attended by homonymous diplopia. Conversely, a like change may occur when the tendency is, in the passive state, to converge.

A very practical illustration of what has been stated may be found in an actual history which I condense for this purpose. In a child with left hyperphoria (or hypertropia) the left eye drifted outward during the first few years of life. (Such a diverging squint is rarely observed by parents unless it is extreme.) At length, presumably as the result of a change in the methods of making the efforts to adjust for the horizontal plane, the squint became convergent. The appearance of the eyes of this patient in early childhood is

represented in Fig. 4, which is copied and enlarged from a daguerreotype picture of him taken at the age of about three years.

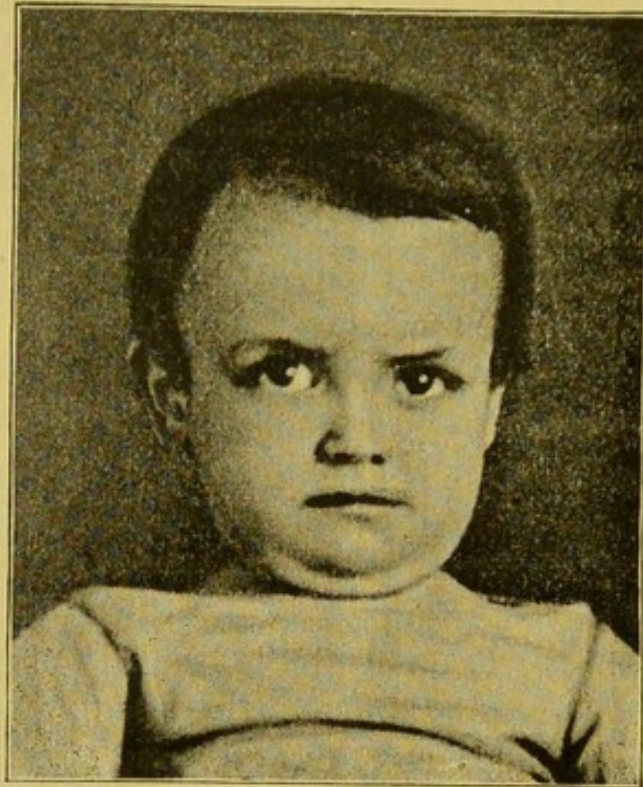


FIG. 4.

It is to be remembered that in the daguerreotype portrait the features are reversed.

About three or four years later, and after the divergence had given place to convergence, a surgeon performed tenotomies of the two recti interni, presumably severing both tendons completely. The result proving an over-correction, the effect of the operation on one eye was modified by the insertion of a (conjunctival?) suture. The result, in view of what has been stated above, was such as we might anticipate. Double vision of the most annoying character was always present. The efforts of many distinguished surgeons to induce these twin images to unite by means of prisms, even for an instant, were fruitless after trials repeated during many years. The case found a prominent place in ophthalmological literature, endorsed by several distinguished surgeons, as one of the class now under discussion. No case could therefore afford us a better model for our study.

It proved easier for this patient to fix objects with the left eye. That being the case, we may suppose that he would make a certain effort of adjustment with the weakened internus of that eye, which would be associated with a corresponding excessive effort of the opposite internus. But these unequal efforts would also be combined with the effort to adjust for the difference in the positions of the images with reference to the horizontal plane. The result would be an excessive rotation of the right eye to the nasal side with homonymous double images. If, on the other hand, a patient with this combination of defects should look at an object which is isolated from other objects which may serve to aid the disabled eye in active adjustment, as, for instance, at a church spire, or at the moon, or a bright star, in which cases only the clear sky is in immediate relation to the object, the most disabled eye would at once drift outward, and crossed diplopia would result. So also, if a small screen were to be interposed between either eye and the object looked at, thus shutting it out from active participation in the effort of adjustment, the covered eye would diverge in a marked manner and would move inward, perhaps to the extent of one third the diameter of the cornea, as soon as the screen should be removed, and then homonymous diplopia would be observed. Or again, if the subject of such a defect were to look through a grating, as, for instance, through the palings of a picket fence, an object seen beyond the fence would be seen doubled, and the diplopia would be crossed; while an object seen between the person and the fence would be double also, but the double images would be homonymous. In the first instance, looking beyond the fence, the adjusting energy of one eye becomes passive, as in the case of looking at the object against the clear sky, with resulting crossed diplopia. In the other instance, looking at the object nearer than the fence, active adjustment of both eyes occurs with excessive convergence and homonymous double images. All these suppositions and conclusions have been fully justified in the actual treatment of these cases.

In certain cases in which this intractable diplopia exists, the patient has the extraordinary faculty of selecting at will

which eye shall fix the object, and the diplopia becomes homonymous or crossed, according as the one or the other eye is engaged in direct fixation. Thus, in the case of a lady patient, if I direct her to look with the right eye, I can see that the eyes are strongly converged, and she reports the presence of homonymous double images. If I then direct her to look with the left eye, the change may require a few seconds or it may take place very quickly. Then the eyes are plainly seen to diverge, and the diplopia is crossed. In such a case, the nervous impulse directed to the right internus is greater than the normal during fixation with that eye, and when a corresponding impulse is sent to the left internus, the eye is caused to swing in excessively and too great convergence results. On the contrary, when the left eye is fixed, there is no such excess of nervous impulse sent to the left internus, and as no excessive impulse is therefore sent to the right internus, that eye swings outward passively, and crossing of images results. But in this explanation we must not lose sight of the important, probably the most important, element in the causation of the inward swing in many if not in the majority of cases. This is the influence of the difference of tension of the muscles which move the eyes in the vertical direction. This influence is often sufficient, even though the moving power of the corresponding lateral muscles should be equal, to cause a swing beyond that which would result from a given impulse to a lateral muscle. I have rarely met with a case of the so-called "antipathy to single vision" in which this element did not play an important rôle.

It needs no argument to show that the defect which causes the patient to have homonymous diplopia when looking at an object, say at twenty feet distance, and heteronymous diplopia when looking at the same object, if a grating, like the fence of which we have spoken, is interposed between the eyes and the object, or which causes the same patient to have homonymous images when looking at an object surrounded by other objects, and crossed images when looking at an object isolated from visible surroundings, lies neither in the brain nor in faulty projection from

the retinae, but in peculiar, although perhaps obscure, defects in the adjusting apparatus.

Homonymous diplopia caused by a brain defect or a retinal defect would remain homonymous under all the circumstances which have just been mentioned. Activity or passivity of certain efforts of adjustment could and would be modified by the circumstances mentioned, and the phenomena resulting, which at first appear confused and irregular, are in reality uniform and in accordance with fixed laws.

It is not to be denied that the investigation of an individual case is often surrounded by immense difficulties, or that each new case may present new and perhaps at first incomprehensible phenomena. It is none the less true that all these cases will be found to be governed by known laws. If the difficulties of interpretation of the phenomena in individual cases are great, it demands the greater skill and patience on the part of the investigator in searching out all the various influences which combine to make the defect.

It would probably be impossible, even if all the facts were in our possession, to lay down distinct rules for the discovery of the exact nature of the faulty relations of muscular tension in each case of this class. To attempt it even to the extent to which the principle has been studied, would be to record separately the experience in each individual case. Enough has been said, however, to indicate the lines on which the investigation is to be made.

In the correction of the defect,—this incompatibility to single seeing,—we must logically seek to re-establish a degree of equilibrium between the mobilizing functions of the opposing muscles. To this end, after first correcting the unequal tendency in the vertical direction, it will, in most instances, be necessary to bring the insertion of the disabled muscle forward, and to reduce the tension of the corresponding one of the other eye. This procedure is by no means as easy as might appear. To readjust the tendon after such a setting back as occurs in the standard squint operation, requires in many instances the most persistent and skilful treatment.

Very little can be accomplished by a gross advancement in which the already disabled muscle is made even less flexible than before. The object is secured by progressive steps, one slight advancement preparing the way for another, until the proper degree of rotation with as great flexibility of the muscle as possible is secured. Then the corresponding muscle of the other eye, if it has not been already relaxed, must be made to assume, as nearly as is required, a corresponding adjustment by a careful relaxation.

Such a procedure has, in my hands, succeeded in establishing binocular vision in many inveterate cases of the so-called "antipathy to single vision." The process is often long and difficult, making the greatest possible demands upon the skill, courage, and patience of the surgeon and of the persistent and intelligent co-operation of the patient.

It has been my purpose to do no more than to indicate in a very general way the principle which I would advance, namely, that incompatibility to single seeing usually denotes incorrect methods of operating, and that there can be no effectual correction of strabismus which leaves the tension of the corresponding muscles of the two eyes unequal. The supposed success of many cases in which such inequality is caused by operation, doubtless results from the fact that in the remaining diplopia the images are so widely separated that the patient does not become aware of its existence.

In order to avoid the evil results of diplopia and to secure not only possible but easy binocular vision, then, we must be guided, first, by the actual rotations of the eyes, and by the actual relation of the visual lines not only in the lateral but in the vertical direction. This can be accomplished only when the patient recognizes the position of double pictures, and this according to the theory of identity. There should be no final operation for the adjustment of squinting eyes, until both patient and surgeon are sure of the relative position of the double images.

A precept which I have elsewhere brought forward is in this connection also of essential importance, viz. :

*"Every modification of the length of a lateral muscle, by relaxation or by shortening, which can in any degree effect the rotation of one eye, should in every instance be accompanied by an exactly equivalent modification of the corresponding muscle of the other eye."*¹

If this precept is correct, the practice of relaxing or setting back of an internus, accompanied by an advancement or shortening of the externus of the same eye while the muscles of the other eye undergo no modification, cannot afford the best results.

The subject of the determination of the relative tensions of the various eye-muscles I have already discussed at some length in a series of articles published in the ARCHIVES OF OPHTHALMOLOGY during the years 1887, 1888, and 1889. It is unnecessary to repeat what has there been said, but there is also much more which might be said in connection with the examination of the relative tensions in these peculiar and most difficult cases, which must be reserved for another occasion.

One point, however, is so important in its relation to the subject under consideration that it should not be separated from it. This is the examination of the comparative rotation of the two eyes in the temporal and in the nasal direction. Something can be learned from an inspection of the movements of the eyes as the surgeon causes the patient to follow with the eyes a pencil or other object as it is carried from side to side, the patient making his best efforts to see it as far toward the extreme outer field of vision at each side as possible. It will in most of the cases, in which the original operation has been performed for converging strabismus, be seen that as the eye on which the operation, or the most extensive operation, has been performed moves toward the nasal side its progress is arrested before the border of the cornea reaches the inner canthus.

The nasal rotation of the other eye will often be found to be free or even excessive. But even the nasal rotation of

¹ Anomalies of the Ocular Muscles, ARCH. OF OPHTHALMOLOGY, 1889, p. 407.

this other eye may be restricted, only in less degree than the first. Similarly we may observe a difference in the temporal rotation. This method of inspection, while it is important and in some measure satisfactory, furnishes less exact information than is required in most cases.

In the measurement of the temporal rotation we have in the perimeter an instrument of sufficient precision. It is my custom to place in the carrier of the perimeter a few capital letters in clear type, of about the size, $2 = D$, of the Snellen scale, and require the patient to see the letters with sufficient clearness to read them. A glass to meet the requirements of the patient's vision is held in such a way before the eye that it is at a right angle to the line between the eye and the test object. Ordinarily a pair of eyes in which no considerable degree of heterophoria exists will make the temporal rotation about 40° each, and no considerable difference in this rotation should exist. In many of the cases under discussion the temporal rotation will be found to differ for the two eyes to the extent of from 10 to 20° . With the new model of the registering perimeter this element can be quickly and accurately determined.

Unfortunately we have no method so accurate for examining the nasal rotation. The full rotation of the eyes in this direction in the normal condition cannot usually be determined by the perimeter, except by the supplementary use of a strong prism. Even with this supplement, the extreme rotation inward of cases of slight converging squint cannot be registered by the instrument. In cases in which the rotation does not much exceed the line of vision across the bridge of the nose, we may place a rounded prism with its apex in the canthus. Two degrees of prism equals one degree of the perimeter. Hence a prism of 10° , apex in the canthus, may cause the eye to turn inward 5° more than it would if looking directly at the object. The expedient of placing a scale of degrees on the lower lid and reading from it the nasal rotation, while inaccurate, is sometimes the only recourse, and the best use of an unsatisfactory method must be made.

